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TECHNICAL REPORT
68-40-ES

A GENERAL NOMOGRAPH FOR NORMAL AND SKEWED FREQUENCY DISTRIBUTIONS: CLIMATOLOGICAL AND OTHER APPLICATIONS

by

EARL E. LACKEY
Earth Sciences Laboratory

July 1967

Project Reference:
1T025001A129

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U.S. Army Materiel Command
U.S. ARMY NATICK LABORATORIES
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FOREWORD

This report is the last in a series of studies by Dr. Earl Lackey, formerly climatologist in the Earth Sciences Laboratory, on methods of predicting climatic probabilities from incomplete data. In this study, a method is developed which portrays effectively the behavior of temperature distributions under a wide variety of climatic conditions. This enables one to make an effective comparison of these climatological variations and also introduces a simple way of extrapolating small amounts of data to what might result if larger amounts were available, by putting all distributions on a comparative basis.

The approach used in this study is somewhat unconventional from the point of view of standard statistical procedures, but because it does throw light upon the behavior of climatological distributions it is presented here for consideration by other investigators in this field.

L. W. TRUEBLOOD
Director
Earth Sciences Laboratory

APPROVED:

DALE H. SIELING
Scientific Director

W. M. MANTZ
Brigadier General, USA
Commanding

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ABSTRACT

Extended experience in the construction and use of several different predictive nomographs covering a wide range of frequency distributions of various types of weather and other phenomena, suggested the probability that a universal series of patterns of frequency distributions might permeate the whole of nature. This study is based in part on the several nomographic patterns developed in previous studies. It assumes that all of the frequency distributions we are likely to encounter in practical climatology, whether symmetrical or asymmetrical (skewed), may be fairly well approximated by a family of cumulative frequency curves, provided they are plotted on such a scale that 100 units represents the whole range of observational experience in each.

The predictive patterns in the General Nomograph and its associated table depend for their operation on the numerical position of the mean (average) between the two extremes (maximum and minimum) in the frequency distribution, when the three related measures are reduced to a 100-unit scale. The means of frequency distributions having various degrees of skewness lie along a diagonal line from the lower left to the upper right of the basic section of the nomograph. Other lines (curved) trace the values of other percentile or fractional parts of the various distributions. The construction, use and reliability of this nomograph and its associated table are given in this report.

Similar predictive patterns in an Alternative Nomograph and its associated table are identified by the numerical position of: (1) the mean maximum between the absolute maximum and the mean minimum, or (2) the mean minimum between the absolute minimum and the mean maximum, depending on which extreme is being explored. A 100-unit scale based on the above values is used in each case. The Alternative Nomograph thus illustrates the possibility of using parametric data other than means and extremes as the basis for a nomograph, if that should be necessary, or should prove to be a better basis for frequency prediction.

The essential summarized data for use with either nomograph may be secured from printed publications or from isothermal maps. How each source of summarized data may be used, for retrieval or predictive purposes, is shown and the results are verified by comparison with recorded data in the same vicinity.

A GENERAL NOMOGRAPH FOR NORMAL AND SKEWED FREQUENCY DISTRIBUTIONS:

CLIMATOLOGICAL AND OTHER APPLICATIONS

Purpose and scope

This study offers a method whereby the detailed climatic record may be retrieved in part by use of a nomographic device in which summarized data may be used effectively to reconstruct the patterns of weather and climatic phenomena inherent in the record. The mean and the extreme values which are available in summarized climatic records are interrelated in such a way that it is possible to discover from them the detailed frequencies of particular climatic values in the past.

The operation of the nomographic method presented here depends largely on the asymmetrical or skewed position of the mean of any given climatic frequency distribution as a measure of central tendency between the extreme maximum and extreme minimum in a frequency distribution. In using the method, those measures are arranged in a numerical sequence and converted to a 100-unit scale, the extremes of which are the extremes of the distribution, 0 to 100, respectively.* A commendable feature of the method is its adaptability to either manual or machine processing.

*It is also possible to base the 100-unit scale on values other than the extremes of the distribution, and use the means of the extremes as measures of skewness. See Part V.

PART I. PRELIMINARY CONSIDERATIONS

1. Some previously published studies

A nomographic method for determining hourly distribution of temperature was published by Spreen in 1956 using the monthly mean, the mean maximum and the mean minimum as the essential measures (11).

Another nomographic method for predicting hourly distribution of temperature was proposed by Lackey in 1960, based on 10-year records, featuring monthly means and the associated 10-year extremes (5). A companion study appeared in 1964 for assessing the percentage frequency and probable amounts of one-day rainfall, based on the mean monthly precipitation, and the maximum one-day rainfall, in a series of 10-year records (7). Other studies by Lackey dealt with maximum temperature probabilities (8) and minimum temperature probabilities (6, 9).

A whole series of U.S. Weather Bureau Technical Papers is devoted to the analysis of weather and climatic data. Several of these deal with frequency and areal distribution of temperature (12). Areal and frequency distribution of precipitation is covered for most of the United States in Technical Report No. 15 with its more than twenty-five separate parts - mostly by states.

A number of in-house U.S. Army Handbooks (10) deal with the analysis of climate at specific locations in different parts of the world. Each of these presents in graphical and tabular form, the frequency and level of temperature distribution to be expected for each month of the year. Some data from three of these Handbooks are discussed in III, 2, this report.

2. Integrating Features

a. Nature and purpose of the 100-unit scale

Very early in our study of arithmetic we learned that in order to compare or combine two or more fractional values, it was necessary to reduce or change them to a common denominator. For example, $1/2 + 1/5 + 1/10 = 5/10 + 2/10 + 1/10 = 8/10$. Later, we discovered we could change all fractional values to a universal denominator - the decimal fraction. Moreover, we learned also that we could reconvert any decimal fraction to an equivalent common fraction with any chosen denominator. For example,

$$0.80 = \frac{80}{100} = \frac{40}{50} = \frac{20}{25} = \frac{16}{20} = \frac{8}{10} = \frac{4}{5} = \frac{2}{2.5} = \frac{1}{1.25}\text{ , etc.}$$

These procedures offer a clue to what is proposed as a method for assessing detailed probabilities from summarized data in which no two records are alike, yet which do have some important elements in common.

b. A symmetrical climatic frequency distribution

In Seoul, Korea, during a 10-July period (310 July days) the daily mean (DMn) temperature was 77°F, the absolute minimum (AbMi) was 57°F and the absolute maximum (AbMx) was 97°F (5, p. 299). Because it lies midway between the extremes, the value of the mean is 50 on the 100-unit scale. A shorter way of stating that relationship is to call 50 a converted mean (CMn).*

Hourly distribution of temperature in Seoul during July is as follows: 1% of the time, 62°F or below; 10% of the time, 67°F or below; 50% of the time, 77°F or below; 90% of the time, 86°F or below; and 99% of the time, 94°F or below. Those expected hourly frequencies happen to be quite symmetrically (normally) distributed, and correspond well to the CMn 50 frequency pattern on the nomograph which is derived from the well-established normal frequency distribution familiar to statisticians.

c. A strongly skewed climatic frequency distribution

However, most distributions are asymmetrical (skewed). That is, their CMn is higher or lower than 50. An example of this is the April rainfall in New Orleans. At New Orleans during a 10-April period (300 April days in 10 years) the monthly mean (MoMn) rainfall was 4.94", and the 1-day maximum (1-day Mx) was 5.89". From the given data, by use of the nomograph, it was found that the converted daily mean (CDMn) pattern was 3. The expected 1-day maximum rainfall on the average was as follows: 1-day in 10 Aprils (1/300): 5.89"; 1 day in 5 Aprils (1/150): 4.35"; 1 day in 50 Aprils (1/1500): 8.60"; 1 day in 100 Aprils (1/3000): 9.90". (See Appendix B for detailed solution and computation of this example.)

The frequency thus described is so far from symmetrical that it would be hard to deal with by reference to normal probability distributions. But the nomograph breaks it down easily into a clear statement of probabilities.

d. Range of converted mean values from these studies

CMn values of the climatic frequency records, used in setting up the General-purpose type Nomograph developed in this and previous studies, have spanned the range 30 to 70 in temperature studies (5), and 1 to 14 in a precipitation study (7). Evident symmetry of curves in the basic section of the nomograph (Figure 1) has permitted its completion in the CMn 15 to 29 and 71 to 100 zones with considerable confidence, even though few actual climatic distributions probably fall in the CMn

*See Appendix A for Abbreviations

70 to 100 range. Symmetry of pattern in the basic section of Figure 1 seems due to the intended and actual near-equivalence of predictive distributions to the actual frequency distributions of climatic observations on which the nomograph is based, and thus by analogy, their equivalence to actual distributions at climatic stations published only in summarized form. However, present proof of the validity of the basic section of the nomograph will be limited here to examples of the empirical tests used in this and prior studies.

PART II. THE GENERAL-PURPOSE NOMOGRAPH

1. Its source and evolution

The integration of the nomographs used in the two studies mentioned in Part I, together with conclusions derived from these two investigations (5, 7) and associated extrapolations, resulted in a prototype general-purpose nomograph similar to Figure 1. After testing and modifying the prototype by use of numerous actual frequency distributions from world-wide sources, both of hourly temperature and 1-day maximum rainfalls, the refined instrument Figure 1 evolved. The frequency distribution of converted predictive values (CPrV), as represented by the prediction pattern of each of the converted means (CMns 1 to 100) and associated converted predictive values (CPrV 0 to 100), were critically examined by use of 4 different types of probability scales.* An attempt was made to devise a mathematical model from which the 100 CMn patterns of the nomograph could be derived. But this did not materialize. Consequently, the completed nomograph is empirically constructed, almost entirely. However, values for CMn 50 and associated CPrV's closely approximate the values taken from a normal frequency table.

2. Description of Nomograph and tabular equivalent

a. Basic section

(1) The nomograph

The square within which the Basic Section of the nomograph is drawn measures 100 units both horizontally and vertically. The vertical lines represent 101 (0 to 100, inclusive) converted predictive values (CPrV). The horizontal lines represent 101 (0 to 100, inclusive) converted means (CMn), and the converted predictive frequency distributions (CPrV) associated with each of them. The curved percentage frequency lines intersect both the CMn and CPrV lines and thus identify the CPrV's associated with particular probability values on each of the 101 CMn patterns. Each of the 101 CMn's on the nomograph is associated with a specific pattern of CPr values. For example, from left to right, the

*Probability Scales:
(1) Normal Probability Scale
(2) Normal-Log Probability Scale
(3) Skew-Log Probability Scale (Lackey, reference 8, Fig. 3)
(4) Extreme Probability Scale (Gumbel, reference 4)

FIGURE 1 - GENERAL-PURPOSE PREDICTIVE NOMOGRAPH: CONVERTED MEANS (CMn) AND ASSOCIATED CONVERTED PREDICTIVE VALUES (CPrV)

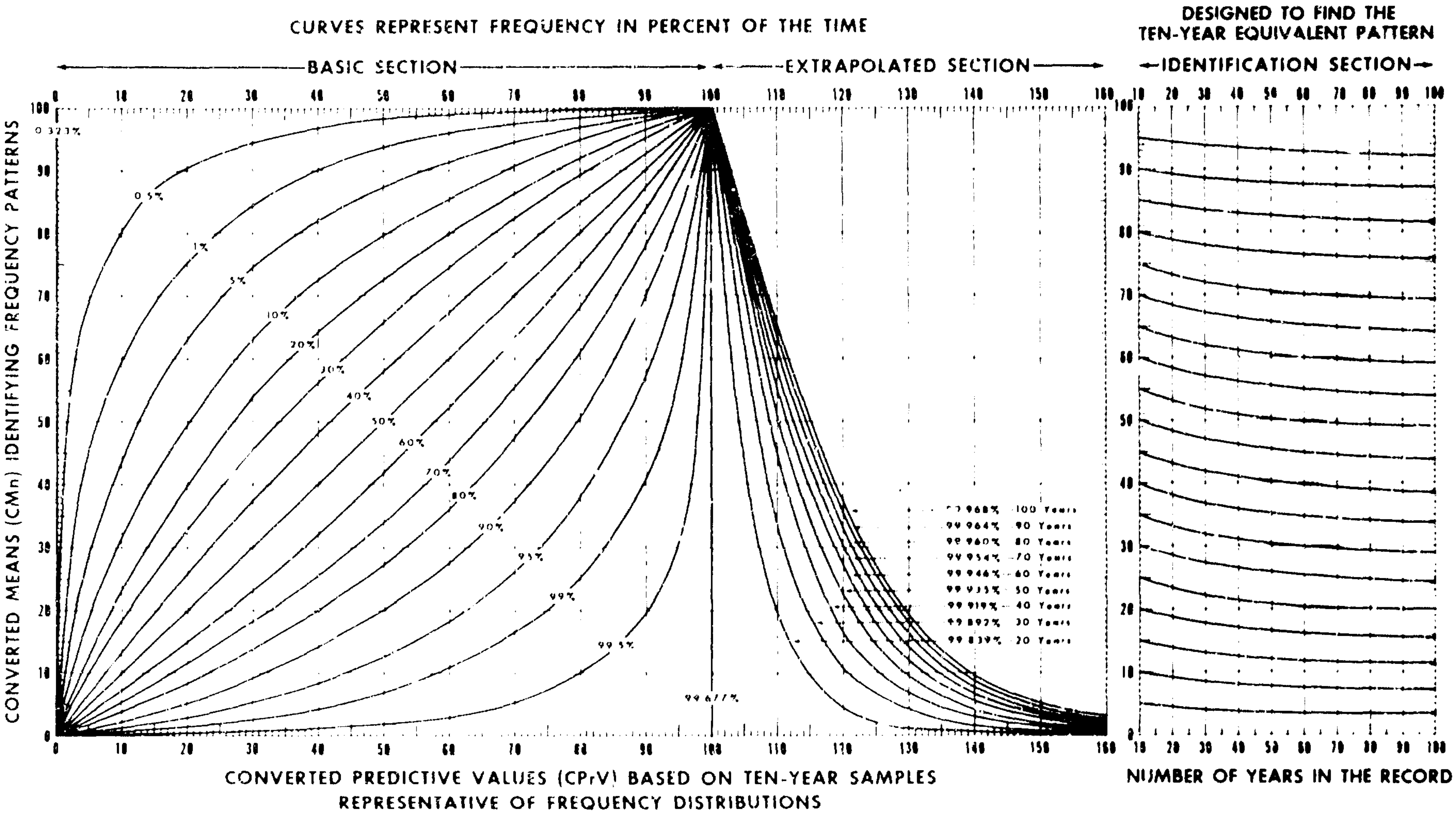

Figure 1

horizontal line of the CMn 60 pattern is crossed by more than a dozen curved percentage frequency lines at CPr values (vertical lines) as follows:

0.5% of the time, CPrV 3	10% of the time, CPrV 27
1% of the time, CPrV 11	20% of the time, CPrV 36
5% of the time, CPrV 18	99% of the time, CPrV 95
	99.5% of the time, CPrV 98.

The 0.323% and 99.677% are the minimum and maximum CPr values, respectively, for the period of observation (10 years). The diagonal (lower left to upper right) defines the asymmetry of each of the CMn patterns and identifies the predictive pattern for each of the 101 cumulative series.

(2) <u>The table</u>

The predictive features of the nomograph are numerically represented in their entirety in Table I. For example, the CPrV 90% column, Basic Section, contains the 101 CPrV's, each associated with 25 curved percentile lines on the nomograph. It is easy to see in the numerical table how each of the predictive patterns differs from every other one, and that each cumulative series in the Basic Section accumulates to 100.

The diversity of the frequency patterns that the nomograph (Fig. 1) and associated table (Table I) afford is illustrated diagrammatically by the three curves in Figure 2.

FIGURE 2: DIAGRAMMATIC SKETCH OF THREE REPRESENTATIVE PATTERNS OF CONVERTED FREQUENCY DISTRIBUTIONS

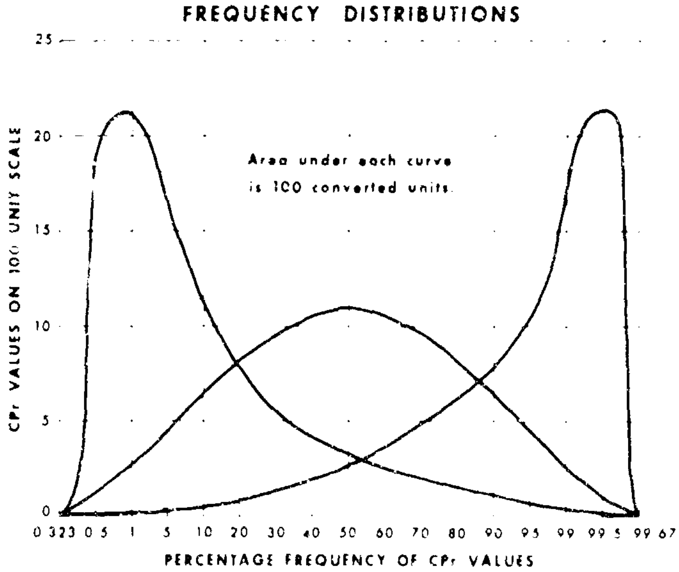

Figure 2

Table I: Tabular Equivalent of General-Purpose Nomograph:
Converted Means (CMn) and Associated Converted Predictive Values (CPrV)

CPrV's in Percentages Based on Ten Samples, Representative of Frequency Distributions of a Given Kind*

CMns	Basic Section 0.32%	0.5%	1%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	99%	99.5%	Extrapolated Section** 10 yrs 99.677%	20 yrs 99.839%	30 yrs 99.892%	40 yrs 99.919%	50 yrs 99.935%	60 yrs 99.946%	70 yrs 99.954%	80 yrs 99.960%	90 yrs 99.964%	100 yrs 99.968%
100	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100 / 100	100	100	100	100	100	100	100	100	100
99	0	60	80	92	94	95	97	98	99	99	99	100	100	100	100	100	100 / 99.0	100 / 99.0	100 / 99.0	100 / 99.0	100 / 99.0	100 / 99.0	100 / 99.0	100 / 99.0	100 / 99.0	101 / 98.0
98	0	45	72	82	88	92	94	96	98	98	99	99	99	100	100	100	100 / 98.0	100 / 98.0	100 / 98.0	100 / 98.0	100 / 98.0	100 / 98.0	100 / 98.0	100 / 98.0	101 / 97.0	101 / 97.0
97	0	40	66	80	85	90	93	95	97	97	98	98	98	99	99	99	100 / 97.0	100 / 97.0	100 / 97.0	100 / 97.0	100 / 97.0	101 / 96.0	101 / 96.0	101 / 96.0	101 / 96.0	102 / 95.1
96	0	36	60	76	83	87	92	94	96	96	97	98	98	99	99	99	100 / 96.0	100 / 96.0	100 / 96.0	100 / 96.0	101 / 95.1	101 / 95.1	101 / 95.1	101 / 95.1	102 / 94.1	102 / 94.1
95	0	32	55	73	80	85	90	93	95	96	97	97	98	98	99	99	100 / 95.0	100 / 95.0	100 / 95.0	101 / 94.6	101 / 94.6	101 / 94.6	102 / 93.1	102 / 93.1	102 / 93.1	102 / 93.1
94	0	29	51	66	[illegible]	84	88	91	94	95	97	97	98	98	99	99	100 / 94.0	100 / 94.0	100 / 94.0	101 / 93.7	101 / 93.7	101 / 93.7	102 / 92.2	102 / 92.2	102 / 92.2	103 / 91.3
93	0	25	47	64	75	82	86	90	93	95	96	97	98	98	99	99	100 / 93.0	100 / 93.0	100 / 93.0	101 / 92.1	101 / 92.1	102 / 91.2	102 / 91.2	102 / 91.2	102 / 91.2	103 / 90.3
92	0	21	44	61	73	80	84	89	92	94	96	97	98	98	99	99	100 / 92.0	100 / 92.0	101 / 91.1	101 / 91.1	102 / 90.2	102 / 90.2	102 / 90.2	102 / 90.2	103 / 89.3	103 / 89.3
91	0	20	42	59	70	78	83	88	91	93	95	96	97	98	98	99	100 / 91.0	100 / 91.0	101 / 90.1	101 / 90.1	102 / 89.2	102 / 89.2	102 / 89.2	103 / 88.3	103 / 88.3	103 / 88.3
90	0	19	40	56	68	76	81	87	90	92	94	96	97	98	98	99	100 / 90.0	100 / 90.0	101 / 89.1	101 / 89.1	102 / 88.2	102 / 88.2	102 / 88.2	103 / 87.4	103 / 87.4	103 / 87.4
89	0	18	38	54	67	75	79	85	89	91	93	95	97	98	98	99	100 / 89.0	100 / 89.0	101 / 88.1	101 / 88.1	102 / 87.3	102 / 87.3	102 / 87.3	103 / 86.4	103 / 86.4	103 / 86.4
88	0	16	36	52	64	73	78	84	88	90	92	95	97	97	98	99	100 / 88.0	101 / 87.1	102 / 86.3	102 / 86.3	[illegible] / 86.3	102 / 86.3	103 / 85.4	103 / 85.4	103 / 85.4	103 / 85.4
87	0	15	34	49	62	71	77	83	87	90	92	94	96	97	98	99	100 / 87.0	101 / 86.1	102 / 85.3	102 / 85.3	102 / 85.3	103 / 84.5	103 / 84.5	103 / 84.5	104 / 83.7	104 / 83.7
86	0	14	32	47	61	69	75	81	86	89	90	93	96	97	98	99	100 / 86.0	101 / 85.1	102 / 84.3	102 / 84.3	103 / 83.5	103 / 83.5	103 / 83.5	103 / 83.5	104 / 82.6	104 / 82.6
85	0	13	31	45	59	67	74	80	85	88	91	93	96	97	98	99	100 / 85.0	101 / 84.2	102 / 83.3	103 / 82.5	103 / 82.5	103 / 82.5	103 / 82.5	104 / 81.7	104 / 81.7	105 / 81.0
84	0	12	30	43	57	65	72	78	84	89	90	93	96	97	98	99	100 / 84.0	101 / 83.2	102 / 82.4	103 / 81.6	103 / 81.6	103 / 81.6	104 / 80.8	104 / 80.8	104 / 80.8	105 / 80.0
83	0	11	28	41	55	63	70	77	83	87	89	91	95	96	98	99	100 / 83.0	101 / 82.2	102 / 81.4	103 / 80.6	103 / 80.6	104 / 79.8	104 / 79.8	105 / 79.0	105 / 79.0	105 / 79.0
82	0	11	27	39	53	62	69	76	82	86	88	91	95	96	98	99	100 / 82.0	101 / 81.1	102 / 80.4	103 / 79.6	103 / 79.6	104 / 78.8	104 / 78.8	105 / 78.1	105 / 78.1	105 / 78.1
81	0	10	25	38	52	61	68	75	81	85	87	91	95	96	98	99	100 / 81.0	101 / 80.2	102 / 79.4	103 / 78.6	104 / 77.9	104 / 77.9	105 / 77.1	105 / 77.1	105 / 77.1	106 / 76.4
80	0	10	24	37	51	60	[illegible]	[illegible]	[illegible]	84	[illegible]	91	94	96	98	99	100 / 80.0	101 / 79.2	102 / 78.4	103 / 77.7	104 / 76.9	105 / 76.2	105 / 76.2	105 / 76.2	106 / 75.5	106 / 75.5
79	0	10	23	35	49	58	65	73	79	84	88	91	94	96	98	99	100 / 79.0	101 / 78.2	102 / 77.5	103 / 76.7	104 / 76.0	105 / 75.2	105 / 75.2	106 / 74.5	106 / 74.5	106 / 74.5
78	0	9	22	33	47	57	62	72	78	83	87	90	94	96	98	99	100 / 78.0	101 / 77.2	102 / 76.5	104 / 75.0	104 / 75.0	105 / 74.3	105 / 74.3	106 / 73.6	107 / 72.9	107 / 72.9
77	0	9	22	32	46	56	63	71	77	82	86	90	93	96	98	99	100 / 77.0	102 / 75.4	103 / 74.8	104 / 74.0	105 / 73.3	105 / 73.3	106 / 72.6	106 / 72.6	107 / 72.0	107 / 72.0
76	0	8	21	31	45	54	62	70	76	81	85	89	93	95	97	99	100 / 76.0	102 / 74.5	103 / 73.8	104 / 73.1	105 / 72.4	105 / 72.4	107 / 71.0	107 / 71.0	107 / 71.0	108 / 70.4
75	0	7	20	30	44	53	60	68	75	80	84	87	92	95	97	99	100 / 75.0	102 / 73.5	103 / 72.8	105 / 71.4	106 / 70.8	106 / 70.8	108 / 69.4	108 / 69.4	108 / 69.4	108 / 69.4

*Frequencies can cover various kinds of distributions - climatic, industrial, psychological, biological, etc.

**In the Extrapolated Section, values more than 100 are [illegible] than 100 are the Period Converted Means. PCMn = $\frac{100\ \text{CMn}}{\text{CPrV}}$

For CMn 90, for example, the 50-year PCMn is $\frac{100 \times 90}{102}$ or 88.2

Table I (continued)
Tabular Equivalent of General-Purpose Nomograph:
Converted Means (CMn) and Associated Converted Predictive Values (CPrV)

CPrV's in Percentages Based on Ten Samples, Representative of Frequency Distributions of a Given Kind*

Basic Section

CMns	0.323%	0.5%	1%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	99%	99.5%
74	0	7	18	29	42	52	58	66	74	79	84	87	92	95	97	99
73	0	6	17	29	41	50	57	65	73	78	83	87	91	94	97	99
72	0	6	17	28	40	49	56	65	72	77	83	87	91	94	97	99
71	0	6	16	27	38	48	56	64	71	77	82	86	90	94	97	99
70	0	5	16	26	37	47	55	63	70	76	81	86	90	94	97	99
69	0	5	15	25	36	46	54	62	69	78	81	86	89	94	97	99
68	0	5	15	24	35	44	53	61	68	75	80	85	89	94	97	99
67	0	4	14	23	34	43	52	60	67	73	79	84	89	94	97	99
66	0	4	14	22	33	42	50	59	66	72	79	83	88	93	96	99
65	0	4	13	21	32	41	49	58	65	71	78	83	88	93	96	99
64	0	4	13	21	31	40	48	57	64	71	78	83	87	93	96	99
63	0	4	12	20	30	39	47	56	63	70	77	82	87	92	96	99
62	0	3	11	20	29	38	46	55	62	69	76	81	86	92	96	99
61	0	3	11	19	28	37	45	53	61	68	75	80	86	92	95	99
60	0	3	11	18	27	36	44	52	60	67	74	79	85	91	95	98
59	0	3	10	18	27	35	43	50	59	66	73	78	85	91	95	98
58	0	3	10	17	26	34	42	49	58	65	72	78	84	90	95	98
57	0	3	9	16	26	34	41	48	57	64	71	77	84	90	95	98
56	0	3	9	16	25	32	40	47	36	63	70	76	83	90	95	98
55	0	2	9	15	24	31	39	47	55	62	70	76	83	89	95	98
54	0	2	8	15	24	30	38	46	54	61	69	75	82	89	95	98
53	0	2	8	14	23	29	37	45	54	60	68	75	82	88	94	98
52	0	2	7	14	22	29	36	44	53	59	67	74	81	88	94	98
51	0	2	7	14	22	28	35	43	51	58	66	73	80	87	94	98
50	0	2	7	13	21	27	34	42	50	57	65	72	79	87	94	98
49	0	2	7	13	20	26	33	40	49	56	64	71	79	86	93	98

Extrapolated Section**

CMns	10 yrs 99.6[illegible]	20 yrs 99.8[illegible]	30 yrs 99.892%	40 yrs 99.919%	50 yrs 99.935%	60 yrs 99.946%	70 yrs 99.954%	80 yrs 99.960%	90 yrs 99.964%	100 yrs 99.968%
74	100	102	103	105	105	106	107	107	108	108
	74.0	72.5	71.9	70.5	70.5	69.8	69.1	69.1	68.5	68.5
73	100	102	103	105	105	106	107	107	108	108
	73.0	71.6	70.9	69.5	69.5	68.9	68.2	68.2	67.6	67.6
72	100	102	103	105	105	106	107	107	108	109
	72.0	71.6	70.9	69.5	69.5	68.9	68.2	68.2	67.6	67.0
71	100	102	103	105	105	107	107	107	109	109
	71.0	69.7	68.9	67.6	67.6	66.4	66.4	66.4	65.1	65.1
70	100	102	104	105	106	107	107	108	109	109
	70.0	68.6	67.3	66.7	66.0	65.4	65.4	64.8	64.2	64.2
69	100	102	104	105	106	107	107	108	109	109
	69.0	67.6	66.3	65.7	65.1	64.5	64.5	63.9	63.3	63.3
68	100	102	104	105	106	107	107	108	109	110
	68.0	66.7	65.4	64.8	64.2	63.6	63.6	63.0	62.4	61.8
67	100	102	104	106	106	107	107	108	109	110
	67.0	65.7	64.4	63.2	63.2	62.6	62.6	62.0	61.5	60.9
66	100	102	104	106	107	108	108	109	110	110
	66.0	64.7	63.5	62.3	61.7	61.1	61.1	60.6	60.0	60.0
65	100	103	105	106	107	108	108	109	110	110
	65.0	63.1	61.9	61.3	60.7	60.1	60.1	59.6	59.1	59.1
64	100	103	105	106	107	108	109	109	110	111
	64.0	62.1	61.0	60.4	59.8	59.3	58.7	58.7	58.2	57.7
63	100	103	105	106	108	108	109	109	110	111
	63.0	61.1	60.0	59.4	58.3	58.3	57.8	57.8	57.2	56.8
62	100	103	105	107	108	108	109	110	111	111
	62.0	60.2	59.0	57.9	57.4	57.4	56.9	56.4	55.9	55.9
61	100	103	105	107	108	109	109	110	111	112
	61.0	59.2	58.1	57.0	56.5	56.0	56.0	55.5	55.0	54.5
60	100	103	105	107	108	109	110	110	111	112
	60.0	58.3	57.1	56.1	55.6	55.0	54.5	54.5	54.1	53.6
59	100	103	106	107	108	109	110	110	111	112
	59.0	57.3	55.7	55.1	54.6	54.1	53.6	53.6	53.2	52.7
58	100	103	106	107	109	109	110	111	112	113
	58.0	56.3	54.7	54.2	53.2	53.2	52.7	52.2	51.8	51.3
57	100	103	106	108	109	110	110	111	112	113
	57.0	55.3	53.8	52.8	52.3	51.8	51.8	51.4	50.9	50.4
56	100	104	106	108	109	110	111	111	112	113
	56.0	53.8	52.8	51.9	51.4	50.9	50.5	50.5	50.0	49.6
55	100	104	106	108	109	110	111	112	113	113
	55.0	52.9	51.9	50.9	50.5	50.0	49.5	49.1	48.7	48.7
54	100	104	106	108	109	110	111	112	113	114
	54.0	51.9	50.9	50.0	49.5	49.1	48.6	48.2	47.8	47.4
53	100	104	106	108	110	111	112	113	114	114
	53.0	51.0	50.0	49.1	48.2	47.7	47.3	46.9	46.5	46.5
52	100	104	107	108	110	111	112	113	114	114
	52.0	50.0	[illegible]	[illegible]	47.3	[illegible]	[illegible]	[illegible]	45.6	45.6
51	100	104	107	109	110	111	112	114	115	115
	51.0	49.0	47.7	46.8	46.4	45.9	45.5	44.7	44.3	44.3
50	100	104	107	109	110	111	113	114	115	115
	50.0	49.1	46.7	45.9	45.5	45.0	44.2	43.9	43.5	43.5
49	100	104	107	109	110	111	113	114	115	115
	49.0	47.1	45.8	45.0	44.5	44.1	43.4	43.0	42.6	42.6

*Frequencies can cover various kinds of distributions - climatic, industrial, psychological, biological, etc.

**In the Extrapolated Section, values more than 100 are the Extrapolated CPrV's. Values less than 100 are the Period Converted Means. $PCMn = \frac{100\ CMn}{CPrV}$

For CMn 90, for example, the 50-year PCMn is $\frac{100 \times 90}{102}$ or 88.2

Table I (continued)
Tabular Equivalent of General-Purpose Nomograph:
Converted Means (CMs) and Associated Converted Predictive Values (CPrV)

CPrV's in Percentages Based on Ten Samples, Representative of Frequency Distributions of a Given Kind*

Basic Section

CMs	0.323%	0.5%	1%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	99%	99.5%
48	0	2	6	12	20	26	32	40	48	55	64	70	78	86	93	98
47	0	2	6	11	19	25	32	39	47	55	63	70	78	85	92	98
46	0	2	6	11	18	24	31	38	46	54	62	69	77	85	92	98
45	0	2	5	10	17	24	30	37	45	53	61	68	76	84	92	97
44	0	2	5	10	16	23	29	36	44	52	60	67	76	84	92	97
43	0	2	5	10	16	21	27	35	43	51	59	66	75	83	91	97
42	0	2	4	9	15	21	26	35	42	50	58	66	74	83	91	97
41	0	2	4	9	15	20	26	34	41	48	57	65	73	82	90	97
40	0	1	4	9	15	20	26	32	40	46	56	64	72	81	89	97
39	0	1	4	8	14	19	25	31	39	46	55	63	72	81	89	97
38	0	1	4	8	14	19	24	31	38	45	54	62	71	80	88	96
37	0	1	4	8	13	18	23	30	37	45	53	61	70	80	88	96
36	0	1	3	7	13	18	22	29	36	44	52	60	69	79	87	96
35	0	1	3	7	12	17	21	28	35	43	51	59	68	78	87	96
34	0	1	3	7	12	17	21	27	34	42	50	58	67	77	87	96
33	0	1	3	6	11	16	20	26	34	41	49	57	66	77	86	96
32	0	1	3	6	10	15	19	25	33	40	48	56	65	76	85	95
31	0	1	3	6	9	15	19	25	32	39	47	55	64	76	85	95
30	0	1	3	6	9	14	18	24	30	38	45	53	63	75	84	95
29	0	1	3	5	9	14	18	23	28	37	44	52	62	74	84	95
28	0	1	2	5	8	13	17	22	27	36	43	51	61	73	83	94
27	0	1	2	5	8	12	17	21	27	35	42	50	59	71	82	94
26	0	1	2	4	7	12	16	20	26	34	41	49	58	70	81	93
25	0	1	2	4	7	11	15	19	25	32	39	47	57	69	80	93
24	0	1	2	4	7	11	14	18	24	31	37	51	56	68	79	93

Extrapolated Section**

CMs	10 yrs 99.677%	20 yrs 99.839%	30 yrs 99.892%	40 yrs 99.919%	50 yrs 99.935%	60 yrs 99.946%	70 yrs 99.954%	80 yrs 99.960%	90 yrs 99.964%	100 yrs 99.968%
48	100	105	107	110	111	112	114	115	116	116
	48.0	45.7	44.9	43.6	43.2	42.9	42.1	41.7	41.4	41.4
47	100	105	107	110	111	112	114	115	116	116
	47.0	44.8	43.9	42.7	42.3	42.0	41.2	40.9	40.5	40.5
46	100	105	107	110	111	112	114	115	116	116
	46.0	43.8	43.0	41.8	41.4	41.1	40.4	40.0	39.7	39.7
45	100	105	107	110	111	113	114	115	116	117
	45.0	42.9	42.1	40.9	40.5	39.8	39.5	39.1	38.8	38.5
44	100	105	108	110	112	113	115	116	117	117
	44.0	41.9	40.7	40.0	39.3	38.9	38.3	37.9	37.6	37.6
43	100	105	108	110	112	113	115	116	117	117
	43.0	41.0	39.9	39.1	38.4	38.1	37.4	37.1	36.8	36.8
42	100	105	108	111	113	114	115	117	118	118
	42.0	40.0	38.9	37.8	37.2	36.8	36.5	35.9	35.6	35.6
41	100	106	109	111	113	114	116	117	118	113
	41.0	38.7	37.6	36.9	36.3	36.0	35.3	35.0	34.7	34.7
40	100	106	109	111	113	115	116	117	118	119
	40.0	37.7	36.7	36.0	35.4	34.8	34.5	34.2	33.9	33.6
39	100	106	109	112	113	115	116	117	119	119
	39.0	36.8	35.8	34.8	34.5	33.9	33.6	33.3	32.8	32.8
38	100	106	109	112	114	116	117	118	119	120
	38.0	35.8	34.9	33.9	33.3	32.8	32.5	32.2	31.9	31.7
37	100	106	109	112	114	116	117	118	119	120
	37.0	34.9	33.9	33.0	32.4	31.9	31.6	31.4	31.1	30.8
36	100	106	110	113	114	117	118	119	120	121
	36.0	34.0	32.7	31.9	31.6	30.8	30.5	30.3	30.0	29.8
35	100	106	110	113	115	117	118	119	120	121
	35.0	33.0	31.8	31.0	30.4	29.9	29.7	29.4	29.2	28.9
34	100	107	110	113	115	117	119	119	121	122
	34.0	31.8	30.9	30.0	29.6	29.1	28.6	28.6	28.1	27.9
33	100	107	110	113	116	118	119	120	121	122
	33.0	30.8	30.0	29.2	28.4	28.0	27.7	27.5	27.3	27.0
32	100	107	110	114	116	118	119	120	121	122
	32.0	29.9	29.1	28.1	27.6	27.1	26.9	26.7	26.4	26.2
31	100	107	111	114	117	119	120	120	122	123
	31.0	29.0	27.9	27.2	26.5	26.1	25.8	25.8	25.4	25.2
30	100	107	111	114	117	119	120	121	122	123
	30.0	29.0	27.0	26.3	25.7	25.2	25.0	24.8	24.5	24.4
29	100	107	111	114	117	119	121	122	123	123
	29.0	27.1	26.1	25.4	24.8	24.4	24.0	23.8	23.6	23.6
28	100	108	112	115	118	120	122	122	123	124
	28.0	25.9	25.0	24.3	23.7	23.3	23.0	23.0	22.8	22.6
27	100	108	112	115	118	120	122	123	124	124
	27.0	25.0	24.1	23.5	22.9	22.5	22.1	22.0	21.8	21.8
26	100	108	112	115	119	120	123	123	124	125
	26.0	24.1	23.2	22.6	21.8	21.6	21.1	21.1	21.0	20.1
25	100	108	113	116	119	121	123	124	125	126
	25.0	23.1	22.1	21.6	21.0	20.7	20.3	20.2	20.0	19.8
24	100	109	113	116	119	122	123	125	126	127
	24.0	22.0	21.2	20.7	20.2	19.7	19.5	19.2	19.0	18.9

*Frequencies can cover various kinds of distributions - climatic, industrial, psychological, biological, etc.

**In the Extrapolated Section, values more than 100 are the Extrapolated CPrV's. Values less than 100 are the Period Converted Means. $PCMs = \frac{100\ CMs}{CPrV}$

For CMs 90, for example, the 50-year PCMs is $\frac{100 \times 90}{102}$ or 88.2

Table I (continued)
Tabular Equivalent of General-Purpose Nomograph:
Converted Means (CMn) and Associated Converted Predictive Values (CPrV)

CPrV's in Percentages Based on Ten Samples, Representative of Frequency Distributions of a Given Kind*

	Basic Section																Extrapolated Section**									
																	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	60 yrs	70 yrs	80 yrs	90 yrs	100 yrs
CMn	0.323%	0.5%	1%	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	99%	99.5%	99.677%	99.839%	99.892%	99.919%	99.935%	99.946%	99.954%	99.960%	99.964%	99.968%
23	0	1	2	4	6	10	13	17	23	30	36	47	54	66	78	92	100	109	113	117	120	122	124	125	127	127
																	23.0	21.1	20.4	19.8	19.2	18.9	18.5	18.3	18.1	18.1
22	0	1	2	4	6	10	12	17	22	29	35	[illegible]	[illegible]	[illegible]	77	[illegible]	100	109	114	117	120	123	124	127	128	128
																	22.0	20.2	[illegible]	18.8	18.3	17.9	17.7	17.3	17.2	17.2
21	0	1	2	4	5	9	12	16	21	28	34	42	51	64	76	92	100	[illegible]	114	117	121	123	125	127	128	128
																	21.0	19.1	18.4	17.9	17.4	17.1	16.8	16.5	16.4	16.4
20	0	1	2	4	5	9	11	15	20	26	33	40	50	63	75	90	100	110	115	118	121	124	126	127	128	129
																	20.0	19.2	17.4	16.9	16.5	16.1	15.9	15.7	15.6	15.5
19	0	1	2	4	5	8	10	15	19	25	31	39	48	61	74	90	100	[illegible]	115	118	122	124	126	128	129	129
																	19.0	17.3	16.5	16.1	15.6	15.3	15.1	14.8	14.7	14.7
18	0	0	2	3	5	8	9	14	18	24	30	37	47	60	73	89	100	111	116	119	122	125	127	128	130	131
																	18.0	16.2	15.5	15.1	14.8	14.4	14.2	14.1	13.8	13.7
17	0	0	2	3	5	7	9	14	17	23	29	35	46	58	72	88	100	111	116	120	123	126	127	129	131	132
																	17.0	15.3	14.7	14.2	13.8	13.5	13.4	13.2	13.0	12.9
16	0	0	2	3	5	7	8	13	16	21	27	33	44	56	70	87	100	112	117	120	123	127	128	129	131	132
																	16.0	14.3	13.7	13.3	13.0	12.6	12.5	12.4	12.2	12.1
15	0	0	2	3	5	6	8	12	15	20	25	32	42	54	67	86	100	112	117	120	124	127	128	130	132	133
																	15.0	13.4	12.8	12.5	12.1	11.8	11.7	11.5	11.4	11.3
14	0	0	2	3	4	6	8	11	14	19	24	30	40	53	65	85	100	113	118	121	125	128	129	131	132	134
																	14.0	12.4	11.9	11.6	11.2	10.9	10.9	10.7	10.6	10.4
13	0	0	1	2	4	5	7	10	13	17	22	28	38	51	64	84	100	113	119	122	126	129	130	132	134	135
																	13.0	11.5	10.9	10.7	10.3	10.1	10.0	9.8	9.7	9.6
12	[illegible]	[illegible]	[illegible]	[illegible]	4	5	7	9	12	16	21	27	36	49	63	83	100	114	119	123	127	130	132	134	135	136
																	12.0	10.5	[illegible]	9.8	9.4	9.2	9.1	9.0	8.9	8.8
11	0	0	1	2	3	4	6	8	11	15	20	25	34	47	60	82	100	114	120	124	128	131	133	135	137	138
																	11.0	9.6	9.2	8.9	8.6	8.4	8.3	8.1	8.0	8.0
10	0	0	1	2	3	4	5	7	10	14	18	24	32	44	58	80	100	115	121	125	130	132	135	136	138	139
																	10.0	8.7	8.2	8.0	7.7	7.6	7.4	7.4	7.2	7.2
9	0	0	1	2	3	4	5	6	9	13	17	23	30	41	56	78	100	115	122	126	131	133	137	138	140	141
																	9.0	7.8	7.4	7.1	6.9	6.8	6.6	6.5	6.4	6.4
8	0	0	1	1	2	3	4	5	8	12	15	21	28	39	54	76	100	116	123	127	132	135	138	140	141	143
																	8.0	6.9	6.5	6.3	6.1	5.9	5.8	5.7	5.7	5.6
7	0	0	1	1	2	3	4	5	7	11	14	19	26	37	52	74	100	117	124	129	133	137	139	141	143	145
																	7.0	6.0	5.6	5.4	5.3	5.1	5.0	5.0	4.9	4.8
6	0	0	1	1	2	3	3	4	6	9	12	16	23	33	49	71	100	[illegible]	126	[illegible]	135	139	142	143	145	148
																	6.0	5.1	4.8	[illegible]	4.4	4.3	4.2	4.2	4.1	4.1
5	0	0	0	1	1	2	3	4	5	7	10	14	20	30	44	68	100	119	128	133	137	141	144	146	148	151
																	5.0	4.2	3.9	3.8	3.6	3.5	3.5	3.4	3.4	3.3
4	0	0	0	1	1	2	2	3	4	6	9	12	17	26	39	63	100	122	131	137	142	146	147	150	155	159
																	4.0	3.3	3.1	2.9	2.8	2.7	2.7	2.7	2.6	2.5
[illegible]	[illegible]	0	0	1	1	1	2	3	3	5	7	10	15	22	35	58	100	124	134	141	146	150	152	155	162	168
																	3.0	2.4	2.2	2.1	2.1	2.0	2.0	1.9	1.9	1.8
2	0	0	0	0	1	1	1	2	2	4	6	8	12	18	28	55	100	126	137	146	151	154	157	160	170	179
																	2.0	[illegible]	[illegible]	1.4	1.3	1.3	1.3	1.3	1.2	
1	0	0	0	0	0	0	1	1	1	2	3	5	6	8	20	40	100	131	145	152	158	166	174	179	185	190
																	1.0	1.0	1.0	1.0	1.0	1.0				
0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	100									
																	0.0									

*Frequencies can cover various kinds of distributions - climatic, industrial, psychological, biological, etc.

**In the Extrapolated Section, values more than 100 are the Extrapolated CPrV's. Values less than 100 are the Period Converted Means. $PCMn = \frac{100\ CMn}{CPrV}$

For CMn 90, for example, the 50-year PCMn is $\frac{100 \times 90}{102}$ or 88.2

b. Extrapolated section

(1) The nomograph

The 101 patterns of converted means (CMns) with their series of cumulated converted predictive values (CPrV's, 0 to 100) each represents a frequency distribution which becomes attenuated from the CMn toward its extremes, but does so at a decelerated rate. A frequency of 1 day in 1 January (1/31) is 3.23% of the time; 1 day in 10 Januaries (1/310) is 0.323% of the time; 1 day in 50 Januaries (1/1550) is .064% of the time; 1 day in 100 Januaries (1/3100) is 0.0323% of the time. This represents deceleration toward infinity. This decelerated decline of frequency in the 10-year record (CPrV 0 to 100 for each CMn value) is continued in the Extrapolated Section of the nomograph and extends to cover climatic frequency probabilities to 100 years (for particular months) by decade accretions.

Thus, we can trace the CMn 60 pattern (mentioned in Basic Section above) beyond the 100 CPrV limits to include 20- 30- 40- 50- 60- 70- 80- 90- and 100-year probabilities with reference to specified months. The extrapolated CPrV's above CPrV 100 for CMn 60 are 103, 105, 107, 108, 109, 110, 110, 111 and 112, respectively. The decelerated trends were derived by reference to long period extremes at numerous stations and also by use of several probability scales (see footnote, II, 1).

(2) The table

As in the Nomograph, the Extrapolated Section of the table is a continuation of the Basic Section, and extends to cover frequency probabilities by decades up to 100 years. Thus, for the CMn 60 pattern we follow the line 60 from the left margin to the required (e.g., 50-yr., 100-yr.) column heading in Extrapolated Section. Values more than 100 are the CPrV's. (Values less than 100 in Extrapolated Section are explained in the Identification Section comments below.)

c. Identification section

(1) The nomograph

The Basic Section of the nomograph was constructed from 10-year records. The trend of converted predictive values on the nomograph and in Table I, therefore, is geared only to 10-year summary records. What is to be done if one must use a 60-year summary record? The Identification Section is designed to cover such contingencies.* Let us assume that a given 60-year record has a converted mean (CMn) of 45. To identify

*See reference 9, Part IV, for full explanation of Identification Section.

the 10-year equivalent pattern for this CMn 45 in Figure 1, follow the vertical 60-year line (Identification Section) downward to horizontal line CMn 45. From here follow the nearest sloping line to the 10-year vertical line on the left margin. It emerges here on CMn 50. For prediction purposes the 10-year CMn 50 pattern of CPrV's should be used as the equivalent of the CMn 45 pattern of CPrV's associated with the 60-year record. In line manner the 10-year equivalent CMn pattern may be identified for the CMn pattern of CPr values for any length of record up to 100 years.

(2) The table

The same results may be achieved by use of Table I. Just follow down the 60-year column (Extrapolated Section) to the 60-year Period Converted Mean (PCMn) nearest 45. (PCMn's are the values in the Extrapolated Section that are less than 100.) The figure nearest to 45 in this column happens to be 45.0, which is the line or pattern of CPrV's associated with the 10-year CMn 50 (far left column). Therefore, the 10-year equivalent CMn 50 pattern of CPrV's is to be used in computing probabilities. (See Appendix C for example using Identification Section.)

PART III. SOME CLIMATOLOGY PREDICTIONS AND THEIR RELIABILITY

1. Assessing rainfall probabilities

Several examples of using the mean and two extremes with a General-purpose type Nomograph to predict frequency and probable amount of 1-day rainfall are given in Reference 7. An example of this type is solved in Appendix B.

2. Validation of certain rainfall predictions by handbook data

Manually tabulated and graphed climatic data for low, middle and high latitudes are given in three Army handbooks: Cristobal, Canal Zone; Devils Lake, North Dakota; and Fort Churchill, Man. (10). Table II gives rainfall data from graphs in these handbooks ("Actual"). Also shown are corresponding predicted values ("Predicted") retrieved by use of the three items of summarized data (AbMx, AbMi and DMn), and the General-purpose Nomograph. The months chosen represent months of the wet or the dry seasons of the year. The predicted values run to 100 years. The graphed values cover only years of actual record.

The differences between the predicted and the actual (tabulated) are not greater than would be expected. In general, the predictions call for a few more days of low rainfall than the tabulated records indicate.

3. Other kinds of climatology problems

Using the mean and two extremes and the General-purpose Nomograph to assess hourly temperature probabilities is discussed in Reference 5 (mentioned above in I, 2b). An example of hourly temperature frequencies is also discussed later in this report (VI, 3) and a detailed solution given in Appendix C.

Summarized data are available for assessing probable percentage data for first killing frosts of Autumn, and last killing frosts of Spring; for the closing of harbors and rivers by ice in Winter and their opening in Spring; and for many other kinds of summarized atmospheric phenomena in which only mean and extremes are given.

Table II: Actual Rainfall Frequencies, Tabulated and Graphed, Compared with Predicted Probabilities*

Days in given mo. - (Ratio: / (Percent: / Months (One per year):		99/100 99% 1	90/100 90% 1	70/100 70% 1	50/100 50% 1	30/100 30% 1	10/100 10% 1	1/100 1.00% 1	1/310 .323% 10	1/620 .161% 20	1/930 .108% 30	1/1240 .0806% 40	1/1550 .0645% 50	1/1860 .0538% 60	1/2170 .0461% 70	1/2480 .0403% 80	1/2790 .0358% 90	1/3100 .0323% 100
Cristobal, C.Z.																		
Predicted	Oct	.00	.02	.25	.50	1.01	1.93	4.12	8.40	9.91	10.58	11.00	11.34	11.68	11.92	12.01	12.18	12.43
Actual	Oct	.00	.00	.03	.18	.65	1.75	6.00		8.00								
Predicted	Mar	.00	.02	.02	.03	.14	.29	.67	3.40	3.02	3.28	3.50	3.62	3.70	3.79	3.84	4.08	4.30
Actual	Mar	.00	.00	.00	.00	.02	.13	1.50		3.50								
Ft. Churchill																		
Predicted	Mar	.00	.00	.02	.07	.16	.31	.70	1.80	2.20	2.36	2.47	2.56	2.63	2.65	2.70	2.80	2.87
Actual	Mar	.00	.00	.00	.00	.00	.40	1.00		2.60								
Predicted	Sep	.00	.00	.00	.13	.24	.45		1.57	1.87	2.01	2.07	2.15	2.21	2.26	2.29	2.32	2.37
Actual	Sep	.00	.00	.00	.00	.04	.20	1.50		2.50								
Devil's Lake, N.D.																		
Predicted	Jun	.00	.03	.06	.11	.26	.49	1.12	2.87	3.50	3.76	3.93	4.08	4.19	4.22	4.31	4.43	4.56
Actual	Jun	.00	.00	.00	.00	.05	.30	1.50		2.50								
Predicted	Mar	.00	.00	.02	.03	.06	.13	.29	.84	1.03	1.13	1.18	1.22	1.26	1.28	1.30	1.36	1.41
Actual	Mar	.00	.00	.00	.00	.00	.06	.60		1.20								

*Predicted = Predicted rainfall amounts and frequencies, calculated from summarized data in Handbooks (AbMx, AbMi, DMn), using the General-purpose Nomograph

Actual = Data manually tabulated and graphed in the respective Handbook (10)

Underlined values are 1-day maxima for specified month, for period of summarized record.

Reading the table: At Cristobal (October), 30% of the time (30 days in 100) one may expect at least 1.01" rain; 0.108% of the time (1 day in 30 Octobers, or 1/930) one should expect at least 10.58"; and 0.461% of the time (1 day in 70 Octobers or 1/2170) one may expect at least 11.92".

PART IV. ILLUSTRATIVE USES FROM INDUSTRY AND PSYCHOLOGY

Many kinds of summarized data are amenable to this nomographic method by which frequency distributions may be resolved. If the mean, the extremes, and length of record are given, the percentage frequency and levels of occurrence may be retrieved or predicted with considerable confidence. Two examples are given below.

1. <u>Comparative screwdriver tensile strengths of slotted heads of valve caps</u>

A potential customer (such as the U. S. Army Materiel Command) desired to know the screwdriver tensile strength of samples of the slotted heads of valve caps of two competing companies. In the given situation the slotted heads of the screw caps could not tolerate tensions greater than 200 lb., and required a minimum strength of at least 140 lb. for satisfactory operations.

Company A: In a 34 valve-cap sample of this company the mean strength was 153 lb., the maximum was 181 lb., and the minimum was 130 lb.

Company B: In a 36 valve-cap sample of the competing company the mean strength was 138 lb., the maximum was 203 lb., and the minimum was 66 lb.

Using these data and the tabular equivalent of the General-purpose Nomograph (Table I), the frequency distribution of tensile strengths was predicted. The frequency distribution in Company A (34 sample records) followed pattern CMn 48. The frequency distribution in Company B (36 sample records) followed pattern CMn 57. The predicted distributions are given in Table III.

Table III. Predicted Frequency and Amount (in lb) of Tensile Strength of Slotted Heads of 2 Competing Valve Caps (Screwdriver Valve Tests)

Company	.0323%	1%	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%	99.84%	99.89%	99.92%	99.954%	99.968%
A	130	133	[140	142	145	149	153	156	161	16[illegible]	167	175	180	<u>181</u>	183	185	186]
B	66	77	99	109	118	127	138	[147	156	164	173	187	197]	201	<u>203</u>	206	210

Underlined figures represent maximum values
Brackets inclose tolerance range [140 - 200 lb]

It is evident from Table III that 90% of Company A valve caps were within the required range (140 to 200 lb.), and that only 50% of Company B valve caps were within this range.

It is conceded that it may seem odd to construct from climatic data a predictive nomograph, and then use it in application to industrial data. But we do use means, standard deviations, etc., regularly as universal measures of dispersion. It is suggested that patterns of asymmetry, in general, are amenable to many more applications.

2. Scores on Army Alpha Test

The summary of scores from an Army Alpha Test given to a group of 54 Army men was as follows: maximum score 201, mean score 172, and minimum score 126 (3). Assuming this to be representative of 10 repeated tests, what are the probable results to be expected at various percentages of the time?

In solving this problem, the converted mean of 61 is used (CMn = 61). Therefore the CPr values in the CMn 61 pattern of Table I (equivalent of the Nomograph) were used to compute the probable percentages of frequency scores. These were found to be: 10% of the men should score 147 or lower; 20%, 154 or lower; 30%, 160 or lower; 50%, 173 or lower; 70%, 182 or lower; 90%, 191 or lower. That is, only 10% of the men should score 191 or above.

If the test had included a larger proportion of easy questions, then the CMn might have been higher, perhaps as high as CMn 80 or 90. The converse probably would happen if there had been a larger proportion of difficult questions in the tests. Or if there had been a large number of such tests, the extremes would probably be more attenuated--perhaps having the maximum higher, and the minimum lower. Then a different nomographic pattern, selected by means of the Identification Section, would be used for predictive purposes, but the distribution pattern would still be approximately as asymmetrical.

PART V. THE ALTERNATIVE NOMOGRAPH

1. Essential data and theory for constructing and using

In summarizing data in which extremes are critical factors, it is often desirable to know the averages of the extremes measured. Therefore, mean maxima (MMx) and mean minima (MMi) for given month(s) are often listed in summary records. The extreme maximum and the extreme minimum temperature for January each usually occurs only once. On the other hand, in January over a period of 50 years there are 1550 daily maxima and 1550 daily minima. The averaging of these gives a January mean daily maximum (MDMx) and a January mean daily minimum (MDMi) each of which is a more stable value from which to measure frequency of daily extremes than any one of its numerous components. It is proposed, therefore, to construct an Alternative All-purpose Nomograph using these two means (MDMx and MDMi) as relatively stable anchors in the abbreviated record from which the frequency of oscillating extremes may be measured.

In such a nomograph the frequency distribution associated with the oscillating **daily minimum** would be measured, located by reference to a 100-unit scale extending from the converted mean daily maximum (CMDMx) = 100 to the absolute minimum (AbMi) = 0. Thus, the converted mean daily minimum (CMDMi) serves to identify the pattern of CPrV's to be used for predictive purposes.

For purposes of predicting the frequency patterns associated with daily maxima or minima, the range should perhaps be measured from one absolute extreme (e.g., AbMx) in a given period of time to the mean of the opposite extreme (e.g., MDMi) instead of measuring from one absolute extreme to the opposite absolute extreme as in Figure 1. We have in Figure 3 such a nomograph. Its construction and use are in most ways analogous to that of Figure 1 of the present study.

2. Previous studies used, and range of converted mean extremes

Two studies (6, 8) served chiefly as guides in constructing the prototype for Figure 3 (Alternative Nomograph). The CMn patterns for the former (CMDMi in reference 6) ranged from CMn 20 to CMn 55, and the CMn patterns for the latter (CMDMx in reference 8) ranged from CMn 36 to CMn 80. (The two series of patterns overlap from CMn 36 to CMn 55.) This left CMn 0 to 20 and CMn 80 to 100 to be developed. The extrapolations were achieved by use of several differing probability scales (see footnote II-2), by searching out some extreme types of distributions, and considering some unusual but theoretically possible situations. For example: a case in which either one or the other or both extremes in several or all of the distributions ran into stationary or fixed limits. Or a situation in which a very potent variable synchronized with other high variables only once or twice in a large number of distributions. In some such cases extremely skewed or asymmetrical distributions might, probably would, occur. In situations like this, converted mean patterns might run high, say 85 to 100 or perhaps low - 0 to 15.

FIGURE 3 - ALTERNATIVE PREDICTIVE NOMOGRAPH: CONVERTED MEAN EXTREMES (CMDMi OR CMDMx) AND ASSOCIATED CONVERTED PREDICTIVE VALUES (CPrV)

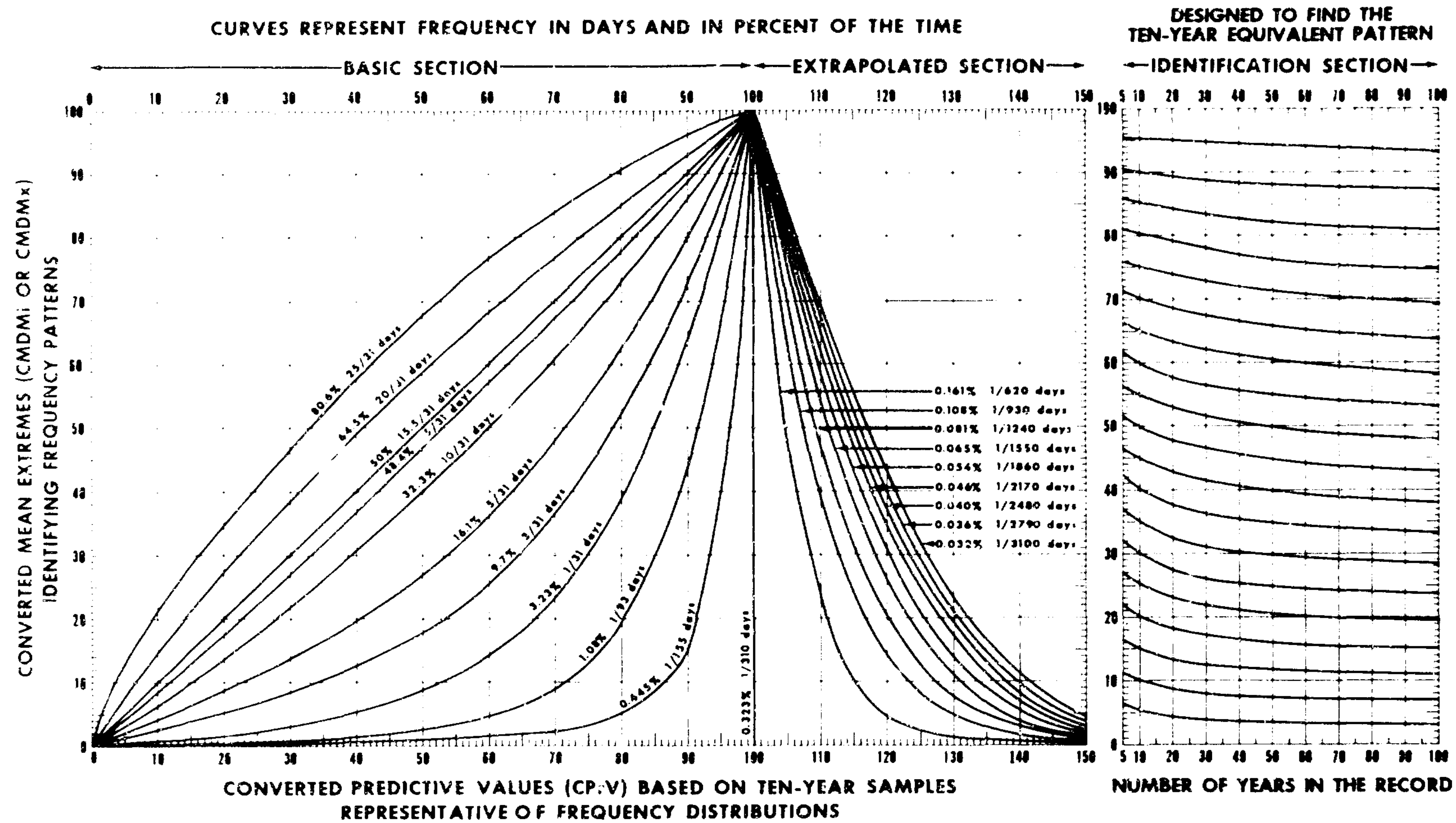

Figure 3

3. Examples of use in predicting

Reference 8 contains several examples of the use of a nomograph similar to this to predict probable frequency of occurrence of daily maximum temperatures. For these the summarized data are: AbMx, MDMx and MDMi. Reference 9 gives an example of predicting probable frequency of daily minimum temperatures. For these the essential data are: AbMi, MDMi and MDMx.

In part VI, 4 of this report January minimum temperature probabilities are given for certain degree quadrangles in Germany.

4. Tabular counterpart

In Table IV the predictive features of the Alternative Nomograph are numerically represented in their entirety. See Part II, 2 of this report, for a generalized explanation of the sections of the table.

5. Differences between the two nomographs

The nomographs are constructed from and used with different items of essential data, as explained above and summarized in VI, 2 below.

In the General-purpose Nomograph, the predictive curves are given in the usual percentages (1%, 5%, 10% 20% . . . 100%). In the Alternative Nomograph the predictive curves are given primarily in frequency in days (25/31, 20/31 . . . 1/3100) with the corresponding percentages (80.6%, 64.5% . . . 0.032%). The latter nomograph has certain advantages for solving climatology problems.

Of course it is immaterial whether the percent frequency curves are arranged from 0 to 100 or from 100 to 0, since on occasion each curve is used as value X or as 100 - X.

Table IV: Tabular Equivalent of Alternative Nomograph:
Converted Mean Extremes (CMEMn or CMEMx) and Associated Converted Predictive Values (CPrV)

CPrV's in Days-Per-Month and Percent of Time, Based on Samples, Representative of Frequency Distributions of a Given Kind*

CMEMn/ CMEMx	99.67% 31/31	80.6% 25/31	64.5% 20/31	48.4% 15/31	32.3% 10/31	16.1% 5/31	9.7% 3/31	3.2% 1/31	1.08% 1/93	0.645% 1/155	0.323% 1/310	0.161% 1/620	0.108% 1/930	0.081% 1/1240	0.065% 1/1550	0.054% 1/1860	0.046% 1/2170	0.040% 1/2480	0.036% 1/2790	0.032% 1/3100
	Basic Section											Extrapolated Section**								
100	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
									100	100	100	100	100	100	100	100	100	100	100	100
99	0	97	98	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
									99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0
98	0	95	97	98	99	99	99	100	100	100	100	100	100	100	100	100	100	100	101	101
									98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	97.0	97.0	97.0
97	0	92	96	97	98	99	99	99	100	100	100	100	100	100	100	100	101	101	101	101
									97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0	96.0	96.0	96.0	96.0
96	0	90	94	97	97	98	99	99	100	100	100	100	100	101	101	101	101	101	101	101
									96.0	96.0	96.0	96.0	96.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0
95	0	90	93	96	97	98	98	99	100	100	100	100	100	101	101	101	101	101	101	102
									95.0	95.0	95.0	95.0	95.0	94.1	94.1	94.1	94.1	94.1	94.1	93.1
94	0	85	92	95	96	97	98	99	99	100	100	100	101	101	101	101	102	102	102	102
									95.9	94.0	94.0	94.0	93.1	93.1	93.1	93.1	92.2	92.2	92.2	92.2
93	0	84	90	94	95	97	98	99	99	100	100	100	101	101	102	102	102	102	102	102
									94.9	93.0	93.0	93.0	92.1	92.1	91.2	91.2	91.2	91.2	91.2	91.2
92	0	83	89	93	95	96	97	98	99	100	100	100	101	101	102	102	102	102	103	103
									93.9	92.0	92.0	92.0	91.1	91.1	90.2	90.2	90.2	90.2	89.3	89.3
91	0	81	88	92	94	96	97	98	99	100	100	100	101	102	102	102	103	103	103	103
									91.9	91.0	91.0	91.0	90.0	89.2	89.2	89.2	88.3	88.3	88.3	88.3
90	0	80	87	91	93	95	97	98	99	100	100	101	101	102	102	103	103	103	103	103
									91.0	90.0	90.0	89.1	89.1	88.2	88.2	87.4	87.4	87.4	87.4	87.4
89	0	78	85	90	92	95	96	98	99	100	100	101	101	102	102	103	103	103	103	104
									89.9	89.0	89.0	88.1	88.1	87.3	87.3	86.4	86.4	86.4	86.4	85.5
88	0	76	84	90	92	94	96	98	99	99	100	101	101	102	103	103	103	104	104	104
									88.8	88.8	88.0	87.1	87.1	86.3	85.4	85.4	85.4	84.6	84.6	84.6
87	0	75	83	89	91	94	96	97	99	99	100	101	102	102	103	103	104	104	104	104
									87.9	87.9	87.0	86.1	85.3	85.3	84.5	84.5	83.7	83.7	83.7	83.7
86	0	72	82	88	90	93	95	97	98	99	100	101	102	102	103	104	104	104	104	105
									87.8	86.9	86.0	85.1	84.3	84.3	83.5	82.7	82.7	82.7	82.7	81.9
85	0	72	80	87	89	93	95	97	98	99	100	101	102	103	103	104	104	105	105	105
									86.7	85.9	85.0	84.2	83.3	82.5	82.5	81.7	81.7	81.0	81.0	81.0
84	0	70	79	86	88	92	95	96	98	99	100	101	102	103	104	104	105	105	105	105
									85.7	84.8	84.0	83.2	82.4	81.6	80.8	80.8	80.0	80.0	80.0	80.0
83	0	69	78	85	88	92	94	96	98	99	100	101	102	103	104	105	105	105	106	106
									84.7	83.8	83.0	82.2	81.4	80.6	79.8	79.0	79.0	79.0	78.3	78.3
82	0	67	77	84	87	91	94	96	98	99	100	101	102	103	104	105	105	106	106	106
									83.6	82.8	82.0	81.1	80.4	79.6	78.8	78.1	78.1	77.4	77.4	77.4
81	0	66	75	83	86	90	93	96	98	99	100	101	102	103	104	105	106	106	106	107
									83.5	81.8	81.0	80.2	79.4	78.6	77.8	77.1	76.4	76.4	76.4	75.7
80	0	65	74	82	85	90	93	95	98	99	100	101	102	104	105	105	106	106	107	107
									81.6	80.8	80.0	79.2	78.4	76.9	76.2	76.2	75.5	75.5	74.8	74.8
79	0	63	73	81	85	89	93	95	97	99	100	102	103	103	104	105	106	106	107	107
									81.4	79.8	79.0	77.5	76.7	76.7	76.0	75.2	74.5	74.5	73.8	73.8
78	0	62	72	80	84	89	92	94	97	99	100	102	103	104	105	105	106	106	107	107
									80.4	78.8	78.0	76.5	75.7	75.0	74.3	74.3	73.6	73.6	72.9	72.9
77	0	61	71	79	83	88	92	94	97	99	100	102	103	104	105	105	106	107	107	108
									79.4	77.8	77.0	75.5	74.8	74.0	73.3	73.3	72.6	72.0	72.0	71.3
76	0	60	70	78	82	88	91	94	97	99	100	102	103	104	105	106	106	107	107	108
									78.4	76.7	76.0	74.5	73.8	73.1	72.4	71.7	71.7	71.0	71.0	70.4
75	0	58	68	78	82	87	91	93	96	99	100	102	103	104	105	106	107	107	108	108
									78.1	75.8	75.0	73.5	72.8	72.1	71.4	70.8	70.1	70.1	69.4	69.4

*Frequencies can cover various kinds of distributions - climatic, industrial, psychological, biological, etc.
**In the Extrapolated Section, values more than 100 are the Extrapolated CPrV's. Values less than 100 are the Period Converted Mean.

$$PCMEMn = \frac{100\ CMEMn}{CPrV} \text{ or } PCMEMx = \frac{100\ CMEMx}{CPrV}$$

Table IV (continued)
Tabular Equivalent of Alternative Nomograph:
Converted Mean Extremes (CMEMl or CMEMx) and Associated Converted Predictive Values (CPrV)

CPrV's in Days-Per-Month and Percent of Time, Based on Samples, Representative of Frequency Distributions of a Given Kind*

CMEMl/ CMEMx	Basic Section 99.677% 31/31	80.6% 25/31	64.5% 20/31	48.4% 15/31	32.3% 10/31	16.1% 5/31	9.7% 3/31	3.23% 1/31	1.08% 1/93	0.645% 1/155	0.323% 1/310	Extrapolated Section** 0.161% 1/620	0.108% 1/930	0.081% 1/1240	0.065% 1/1550	0.054% 1/1860	0.046% 1/2170	0.040% 1/2480	0.036% 1/2790	0.032% 1/3100
74	0	57	67	77	81	87	90	93	96	99	100	102	103	104	105	106	107	107	108	109
									77.1	74.7	74.0	72.5	71.8	71.2	70.5	69.8	69.2	69.2	68.3	67.9
73	0	56	66	76	80	86	90	93	96	99	100	102	104	104	106	106	107	108	108	109
									76.0	73.7	73.0	71.6	70.2	70.2	68.9	68.9	68.2	67.6	67.6	67.0
72	0	55	65	75	79	86	90	92	96	98	100	102	104	105	106	107	107	108	109	109
									75.0	73.5	72.0	70.6	69.2	68.6	67.9	67.3	67.3	66.7	66.1	66.1
71	0	54	64	74	79	85	89	92	96	98	100	102	104	105	106	107	108	108	109	110
									74.0	72.4	71.0	69.6	68.3	67.6	67.0	66.4	65.7	65.7	65.1	64.5
70	0	53	62	73	77	84	89	92	96	98	100	102	104	105	106	107	108	109	109	110
									72.9	71.4	70.0	68.6	67.3	66.7	66.0	65.4	64.8	64.2	64.2	63.6
69	0	51	61	72	77	84	88	91	95	98	100	102	104	105	106	107	108	109	110	110
									72.6	70.4	69.0	67.6	66.3	65.7	65.1	64.5	63.9	63.3	62.7	62.7
68	0	50	60	71	76	83	88	91	95	98	100	103	104	105	106	107	108	109	110	111
									71.6	69.4	68.0	66.0	65.4	64.8	64.2	63.6	63.0	62.3	61.8	61.3
67	0	49	59	70	75	83	88	91	95	98	100	103	104	105	105	107	108	109	110	111
									70.5	68.4	67.0	65.0	64.4	63.8	63.2	62.6	62.0	61.5	60.9	60.4
66	0	48	58	69	74	82	87	91	95	98	100	103	105	106	107	108	109	110	110	111
									69.5	67.3	66.0	64.1	62.9	62.3	61.7	61.1	60.1	60.0	60.0	59.5
65	0	47	57	68	73	81	86	90	95	98	100	103	105	106	107	108	109	110	111	112
									68.4	66.3	65.0	63.1	61.9	61.3	60.7	60.2	59.6	59.1	58.6	58.0
64	0	46	56	67	73	81	86	90	95	98	100	103	105	106	108	109	110	110	111	112
									67.4	65.3	64.0	62.1	61.0	60.4	59.3	58.7	58.2	58.2	57.7	57.1
63	0	46	56	67	73	81	86	90	94	98	100	103	105	106	108	109	110	111	112	112
									67.0	64.3	63.0	61.2	60.0	59.4	58.3	57.7	57.3	56.8	56.3	56.3
62	0	45	54	65	71	80	85	89	94	98	100	103	105	106	108	109	110	111	112	113
									66.0	63.3	62.0	60.2	59.1	58.5	57.4	56.9	56.4	55.9	55.4	54.9
61	0	44	53	64	70	79	85	89	94	98	100	103	105	106	108	109	110	111	112	113
									64.9	62.2	61.0	59.2	58.1	57.6	56.5	56.0	55.5	55.0	54.5	54.0
60	0	42	51	63	69	78	84	89	94	97	100	104	106	107	108	110	111	111	112	113
									63.8	61.9	60.0	57.7	56.6	56.1	55.5	54.5	54.1	54.1	53.6	53.1
59	0	42	51	62	68	78	84	88	93	97	100	104	106	107	109	110	111	112	113	114
									63.4	60.8	59.0	56.7	55.7	55.1	54.1	53.6	53.2	52.9	52.2	51.8
58	0	41	49	61	67	77	83	88	93	97	100	104	106	107	109	110	111	112	113	114
									62.4	59.8	58.0	55.8	54.7	54.2	53.2	52.7	52.3	51.9	51.3	50.9
57	0	40	48	60	66	76	83	88	93	97	100	104	106	108	109	111	112	113	114	115
									61.3	58.8	57.0	54.2	53.8	52.8	52.3	51.4	50.9	50.4	50.0	49.6
[illegible]	[illegible]	39	47	59	66	76	82	87	93	97	100	104	106	108	110	111	112	113	114	115
									60.2	[illegible]	[illegible]	53.8	52.8	51.9	50.9	50.4	50.0	49.6	49.1	48.7
55	0	38	46	58	65	75	82	87	93	97	100	104	107	108	110	111	112	113	114	115
									59.1	56.7	55.0	52.9	51.4	50.9	50.0	49.5	49.1	48.7	48.2	47.8
54	0	37	45	57	64	74	81	86	92	97	100	104	107	108	110	111	112	113	115	116
									58.7	55.7	54.0	51.9	50.5	50.0	49.1	48.6	48.2	47.8	47.0	46.6
[illegible]	[illegible]	[illegible]	[illegible]	56	63	[illegible]	[illegible]	86	92	97	100	104	107	108	110	112	113	114	115	116
									57.6	54.6	53.0	51.0	49.5	49.1	48.2	47.3	46.9	46.5	46.1	45.7
52	0	35	43	55	62	73	80	86	92	96	100	104	107	109	111	112	113	114	115	116
									56.5	54.2	52.0	50.0	48.6	47.7	46.8	46.4	46.0	45.6	45.2	44.8
51	0	33	42	53	60	71	79	85	92	96	100	105	107	[illegible]	111	[illegible]	[illegible]	[illegible]	116	117
									55.4	53.1	51.0	48.6	47.7	46.8	45.9	45.1	44.7	44.3	44.0	43.6
50	0	33	41	53	60	71	79	85	91	96	100	105	107	109	111	113	114	115	116	117
									54.9	52.0	50.0	47.6	46.7	45.9	45.0	44.2	43.9	43.5	43.1	42.7

*Frequencies can cover various kinds of distributions - climatic, industrial, psychological, biological, etc.
**In the Extrapolated Section, values <u>more</u> than 100 are the Extrapolated CPrV's. Values <u>less</u> than 100 are the Period Converted Mean.

$$PCMEMl = \frac{100\ CMEMl}{CPrV} \text{ or } PCMEMx = \frac{100\ CMEMx}{CPrV}$$

Table IV (continued)
Tabular Equivalent of Alternative Nomograph:
Converted Mean Extremes (CMEMi or CMEMx) and Associated Converted Predictive Values (CPrV)

CPrV's in Days-Per-Month and Percent of Time, Based on Samples, Representative of Frequency Distributions of a Given Kind*

CMEMi/	Basic Section											Extrapolated Section**								
	99.67%	80.6%	64.5%	48.4%	32.3%	16.1%	9.7%	3.2%	1.08%	0.645%	0.323%	0.161%	0.108%	0.081%	0.065%	0.054%	0.046%	0.040%	0.036%	0.032%
CMEMx	31/31	25/31	20/31	15/31	10/31	5/31	3/31	1/31	1/93	1/155	1/310	1/620	1/930	1/1240	1/1550	1/1860	1/2170	1/2480	1/2790	1/3100
49	0	32	40	52	59	71	78	85	91	96	100	105	108	109	111	113	114	115	116	118
									53.8	51.0	49.0	46.7	45.4	45.0	44.1	43.4	43.0	42.6	42.2	41.5
48	0	32	39	51	58	70	78	84	91	96	100	105	108	110	112	113	115	116	117	118
									52.7	50.0	48.0	45.7	44.4	43.6	42.9	42.5	41.7	41.4	41.0	40.7
47	0	30	38	50	57	69	77	84	91	96	100	105	108	110	112	114	115	117	118	119
									51.6	49.0	47.0	44.8	43.5	42.7	42.0	41.2	40.9	40.2	39.8	39.5
46	0	30	38	49	57	68	76	83	91	96	100	105	108	110	112	114	115	116	117	119
									50.5	47.9	46.0	43.8	42.6	41.8	41.1	40.4	40.0	39.7	39.3	38.7
45	0	29	37	49	56	68	76	83	90	96	100	105	108	110	112	114	115	116	118	119
									50.0	46.9	45.0	42.9	41.7	40.9	40.2	39.3	39.1	38.8	38.1	37.8
44	0	28	36	47	54	67	75	82	90	96	100	105	109	111	113	115	116	117	118	120
									48.9	45.8	44.0	41.5	40.4	39.6	38.9	38.3	37.9	37.6	37.3	36.6
43	0	27	34	46	53	66	75	82	90	95	100	106	109	111	113	115	116	118	119	120
									47.7	45.2	43.0	40.6	39.4	38.7	38.1	37.4	37.1	36.4	36.2	35.8
42	0	26	33	45	52	65	74	81	89	95	100	106	109	111	114	115	117	118	119	121
									47.2	44.2	42.0	39.6	38.5	37.8	36.8	36.5	35.9	35.6	35.3	35.0
41	0	25	32	44	51	64	73	81	89	95	100	106	109	112	114	116	117	118	119	121
									46.1	43.2	41.0	38.7	37.6	36.6	36.0	35.3	35.0	34.7	34.5	33.9
40	0	23	31	43	50	63	72	80	89	95	100	106	110	112	114	116	118	119	120	121
									44.9	42.1	40.0	37.7	36.4	35.7	35.1	34.5	33.9	33.6	33.3	33.1
39	0	23	31	42	49	62	72	80	89	95	100	106	110	112	115	116	118	119	120	122
									43.8	41.1	39.0	36.7	35.5	34.8	33.9	33.6	33.1	32.8	32.5	31.0
38	0	22	30	41	48	62	71	79	88	95	100	107	110	113	115	117	118	120	121	122
									43.2	40.0	38.0	35.5	34.5	33.6	33.0	32.5	32.2	31.7	31.4	31.1
37	0	22	29	40	47	61	70	79	88	94	100	107	110	113	115	117	119	120	121	123
									42.0	39.4	37.0	34.6	33.6	32.7	32.3	31.6	31.1	30.8	30.6	30.1
36	0	21	28	39	46	60	69	78	88	94	100	107	111	113	116	118	119	121	122	123
									40.9	38.3	36.0	33.6	32.4	31.9	31.0	30.5	30.3	29.8	29.5	29.3
35	0	20	26	38	45	59	69	78	87	94	100	107	111	114	116	118	120	121	122	124
									40.2	37.2	35.0	32.7	31.5	30.7	30.2	29.7	29.2	28.9	28.7	28.2
34	0	20	26	37	44	58	68	77	87	94	100	108	111	114	117	119	120	121	122	124
									39.1	36.2	34.0	31.5	30.6	29.8	29.1	28.6	28.3	28.1	27.9	27.4
33	0	19	25	36	43	57	67	77	86	94	100	108	112	114	117	119	121	122	123	125
									38.4	35.1	33.0	30.6	29.5	28.9	28.2	27.7	27.3	27.0	26.8	26.4
32	0	18	24	35	42	56	66	76	86	93	100	108	112	115	117	119	121	122	124	125
									37.2	34.4	32.0	29.6	28.6	27.8	27.4	26.9	26.4	26.2	25.8	25.6
31	0	18	23	33	40	54	65	75	85	93	100	108	112	115	118	120	121	122	124	126
									36.5	33.3	31.0	28.7	27.7	27.0	26.2	25.8	25.6	25.4	25.0	24.6
30	0	16	22	33	39	53	65	75	85	93	100	109	113	116	118	120	122	123	125	126
									35.3	32.2	30.0	27.5	26.5	25.9	25.4	25.0	24.6	24.4	24.0	23.8
29	0	15	21	32	38	52	64	74	85	93	100	109	113	116	119	121	123	124	125	127
									34.1	31.5	29.0	26.6	25.7	25.0	24.4	24.0	23.6	23.4	23.2	22.8
28	0	15	21	31	38	52	63	74	84	93	100	109	113	117	119	121	123	125	126	127
									33.3	30.1	28.0	25.7	24.8	23.9	23.5	23.1	22.8	22.5	22.2	22.0
27	0	14	20	30	36	50	62	73	84	93	100	109	114	117	120	122	124	125	126	127
									32.1	29.0	27.0	24.8	23.7	23.1	22.5	22.1	21.8	21.5	21.4	21.3
[illegible]	0	13	19	29	35	49	61	72	83	92	100	110	114	117	120	122	125	[illegible]	[illegible]	128
									31.3	28.3	[illegible]	23.0	22.0	22.2	21.7	21.3	20.8	20.6	20.5	20.3
25	0	13	18	28	34	48	59	71	83	92	100	110	115	118	120	123	125	126	127	128
									30.1	27.2	25.0	22.7	21.7	21.2	20.8	20.3	20.0	19.8	19.7	19.4

*Frequencies can cover various kinds of distributions - climatic, industrial, psychological, biological, etc.
In the Extrapolated Section, values **more than 100 are the Extrapolated CPrV's. Values **less** than 100 are the Period Converted Mean.

$$PCMEMi = \frac{100\ CMEMi}{CPrV} \text{ or } PCMEMx = \frac{100\ CMEMx}{CPrV}$$

Table IV (continued)
Tabular Equivalent of Alternative Nomograph:
Converted Mean Extremes (CMDMi or CMDMx) and Associated Converted Predictive Values (CPrV)

CPrV's in Days-Per-Month and Percent of Time, Based on Samples, Representative of Frequency Distributions of a Given Kind*

CMDMi/ CMDMx	Basic Section 99.677% 31/31	80.6% 25/31	64.5% 20/31	48.4% 15/31	32.3% 10/31	16.1% 5/31	9.7% 3/31	3.2% 1/31	1.08% 1/93	0.645% 1/155	0.323% 1/310	Extrapolated Section** 0.161% 1/620	0.108% 1/930	0.081% 1/1240	0.065% 1/1550	0.054% 1/1860	0.046% 1/2170	0.040% 1/2480	0.036% 1/2790	0.032% 1/3100
24	0	12	17	27	33	47	58	70	82	92	100	110	115	118	121	123	126	127	128	130
									29.3	26.1	24.0	21.8	20.9	20.3	19.8	19.5	19.0	18.9	18.8	18.5
23	0	11	17	26	32	45	57	70	82	92	100	110	115	119	122	124	126	128	129	130
									28.0	25.0	23.0	20.9	20.0	19.3	18.9	18.5	18.3	18.0	17.8	17.7
22	0	11	16	25	30	44	56	69	81	92	100	110	115	119	122	124	127	128	129	131
									27.2	23.9	22.0	20.0	19.1	18.5	18.0	17.7	17.3	17.2	17.1	16.8
21	0	10	15	24	29	42	55	68	81	91	100	111	116	120	123	126	128	130	131	132
									25.9	23.1	21.0	18.9	18.1	17.5	17.1	16.7	16.4	16.2	16.0	15.9
20	0	9	14	22	28	40	53	67	80	91	100	111	117	121	124	126	128	130	131	132
									25.0	22.0	20.0	18.0	17.1	16.5	16.1	15.9	15.6	15.4	15.3	15.2
19	0	9	13	22	27	39	52	66	80	91	100	111	118	121	124	126	129	130	131	132
									23.8	20.9	19.0	17.1	16.2	15.7	15.3	15.1	14.7	14.6	14.5	14.4
18	0	8	13	20	25	38	50	65	79	91	100	111	118	122	125	127	129	131	132	133
									22.8	19.8	18.0	16.2	15.3	14.8	14.4	14.2	14.0	13.7	13.6	13.5
17	0	8	12	19	24	36	48	63	78	90	100	112	118	122	125	127	129	132	133	135
									21.8	18.9	17.0	15.2	14.4	13.9	13.6	13.4	13.2	12.9	12.8	12.6
16	0	7	11	18	23	34	47	62	78	90	100	112	119	122	126	128	131	132	134	135
									20.5	17.7	16.0	14.2	13.4	13.1	12.7	12.5	12.2	12.1	11.9	11.8
15	0	6	10	17	22	33	45	61	77	90	100	113	119	123	126	129	132	133	135	136
									19.5	16.7	15.0	13.3	12.6	12.2	11.9	11.6	11.4	11.3	11.1	11.0
14	0	6	9	16	21	30	43	59	76	89	100	113	120	124	127	130	132	134	135	137
									18.4	15.7	14.0	12.4	11.7	11.3	11.0	10.8	10.6	10.4	10.4	10.2
13	0	6	9	15	20	29	41	58	75	89	100	113	120	125	128	131	133	135	136	138
									17.3	[illegible]	13.0	11.5	10.8	10.4	10.2	9.9	9.8	9.6	9.5	9.4
12	0	5	8	14	18	27	39	56	74	88	100	114	122	125	129	132	135	136	137	139
									16.2	13.6	12.0	10.5	9.8	9.6	9.3	9.1	8.9	8.8	8.8	8.6
11	0	4	8	13	17	25	37	55	73	88	100	114	122	126	130	133	135	137	138	140
									15.1	13.0	11.0	9.6	9.0	8.7	8.5	8.3	8.1	8.0	8.0	7.9
10	0	4	7	12	15	22	35	53	72	87	100	115	123	127	131	134	136	138	139	141
									13.9	11.5	10.0	8.7	8.1	7.9	7.6	7.5	7.4	7.2	7.2	7.1
9	0	3	6	11	14	21	31	50	70	86	100	116	124	128	132	135	137	139	141	142
									12.9	10.5	9.0	8.7	7.3	7.0	6.8	6.7	6.6	6.5	6.4	6.3
8	0	3	6	9	12	18	28	48	68	85	100	116	125	130	133	136	138	140	142	144
									11.8	9.4	8.0	6.9	6.4	6.2	6.0	5.9	5.8	5.7	5.6	5.6
7	0	3	5	7	11	16	26	46	67	84	100	117	126	131	134	137	140	142	143	145
									10.4	8.3	7.0	6.0	5.6	5.3	5.2	5.1	5.0	4.9	4.9	4.8
6	0	2	4	7	10	15	23	43	65	82	100	118	128	132	136	139	141	143	145	147
									9.2	7.3	6.0	5.1	4.7	4.5	4.4	4.3	4.3	4.2	4.1	4.1
5	0	2	3	6	7	12	20	39	62	81	100	119	129	134	[illegible]	[illegible]	[illegible]	143	147	149
									[illegible]	[illegible]	5.0	4.2	3.9	3.7	3.6	3.5	3.5	3.5	3.4	3.4
4	0	1	3	5	7	10	16	35	59	78	100	120	131	136	140	142	145	147	150	153
									6.8	5.1	4.0	3.3	3.1	2.9	2.9	2.8	2.8	2.7	2.7	
3	0	1	2	4	5	7	11	33	52	74	100	123	134	139	142	145	147	149	150	158
									5.7	4.1	3.0	2.4	2.2	2.2	2.1	2.1	2.0	2.0	1.9	
2	[illegible]	[illegible]	[illegible]	[illegible]	3	5	7	27	50	70	100	[illegible]	137	143	145	148	150	160	162	165
									4.0	2.9	2.0	1.6	1.5	1.4	1.4	1.4	1.3			
1	0	1	1	2	2	3	5	15	35	50	100	130	142	150	151	155	158	172	175	177
									2.9	2.0	1.0	0.8	0.7	0.6	0.6					
0	0	0	0	0	0	0	0	0	0	0	100									

*Frequencies can cover various kinds of distributions - climatic, industrial, psychological, biological, etc.
**In the Extrapolated Section, values more than 100 are the Extrapolated CPrV's. Values less than 100 are the Period Converted Mean.

$$PCMDMi = \frac{100\ CMDMi}{CPrV} \text{ or } PCMDMx = \frac{100\ CMDMx}{CPrV}$$

PART VI. USE OF THE NOMOGRAPHS WITH ISOTHERMAL MAPS

The nomographs described have special significance as applied to climatic data. Let us illustrate one use, potentially world-wide, by applying it to a specific country - Germany.

1. <u>Constructing isothermal maps of essential data</u>

Summarized temperature data from 75 weather stations in Germany (Fig. 4) enabled us to construct 5 January isothermal maps of the country based on more than 70 50-year records:

AbMi (Fig. 5a); MDMi (Fig. 5b); MoMn (Fig. 5c);
MDMx (Fig. 5d); AbMx (Fig. 5e).

2. <u>Predicting frequency distribution of (January) temperatures</u>

With these maps of essential data and the appropriate nomograph, we can predict the hourly frequency distribution of January temperature for any given place in Germany.

<u>Which</u> 3 items of essential data we use will depend on which nomograph we intend to use. These would be:

For the General-purpose Nomograph:

AbMx MoMn AbMi

For the Alternative Nomograph:

AbMi MDMi MDMx <u>or</u> AbMx MDMx MDMi

For solving the present problem, the General-purpose Nomograph was selected.

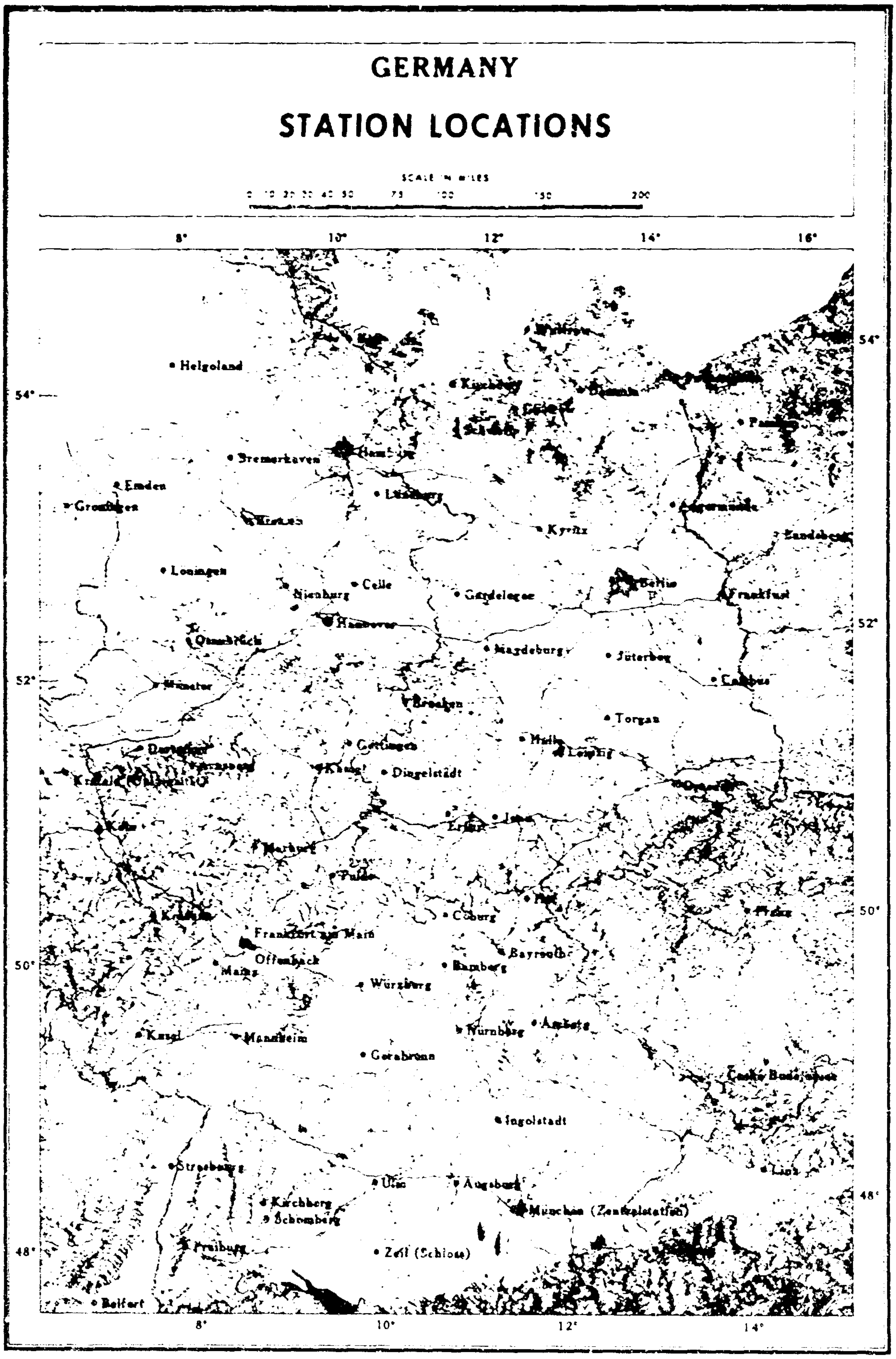
GERMANY
STATION LOCATIONS
Helgoland
Bremerhaven
Emden
Loningen
Nienburg
Celle
Gardelegen
Magdeburg
Jüterbog
Kyritz
Torgau
Dingelstädt
Jena
Coburg
Frankfurt am Main
Offenbach
Bamberg
Würzburg
Nürnberg
Gerabronn
Ingolstadt
Augsburg
Ulm
München (Zentralstation)
Kirchberg
Schömberg
Zeil (Schloss)
Belfort
Straßburg

Figure 4

GERMANY

JANUARY ABSOLUTE MINIMUM TEMPERATURE (AbMi) - °F.

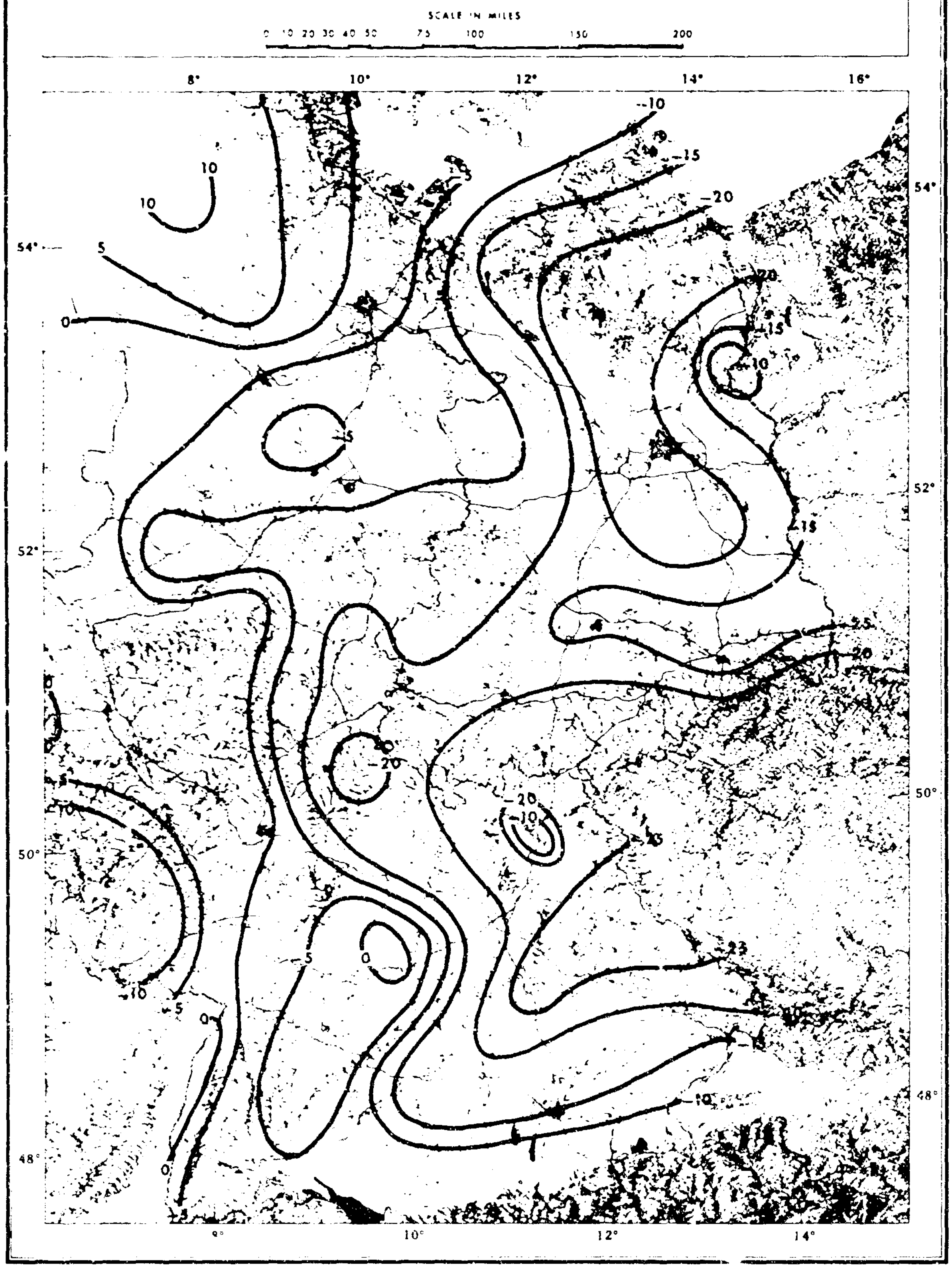

Figure 5a
27

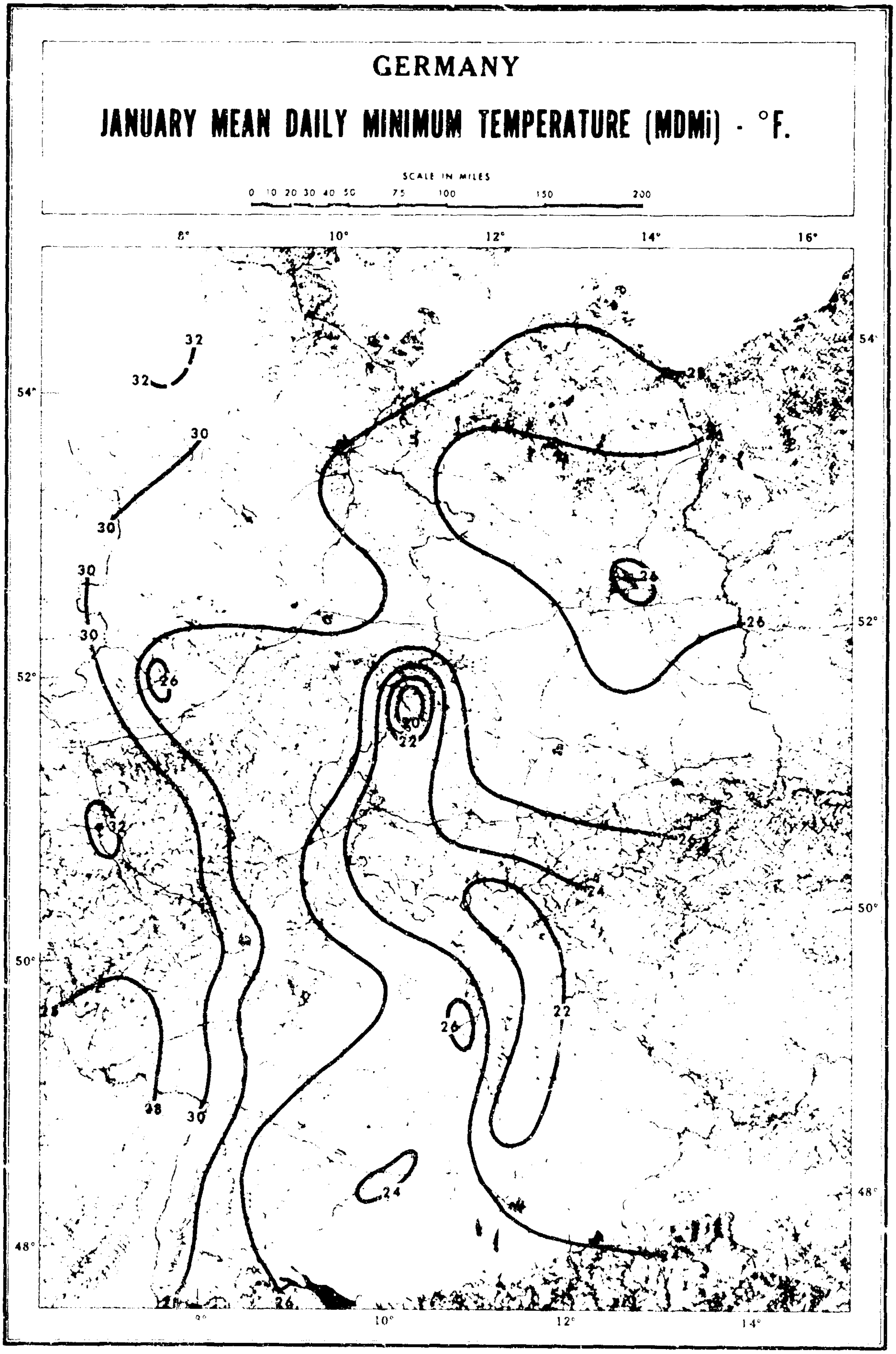
GERMANY
JANUARY MEAN DAILY MINIMUM TEMPERATURE (MDMi) - °F.
SCALE IN MILES
0 10 20 30 40 50 75 100 150 200
8°
10°
12°
14°
16°
54°
52°
50°
48°
32
30
28
26
24
22
20

Figure 5b

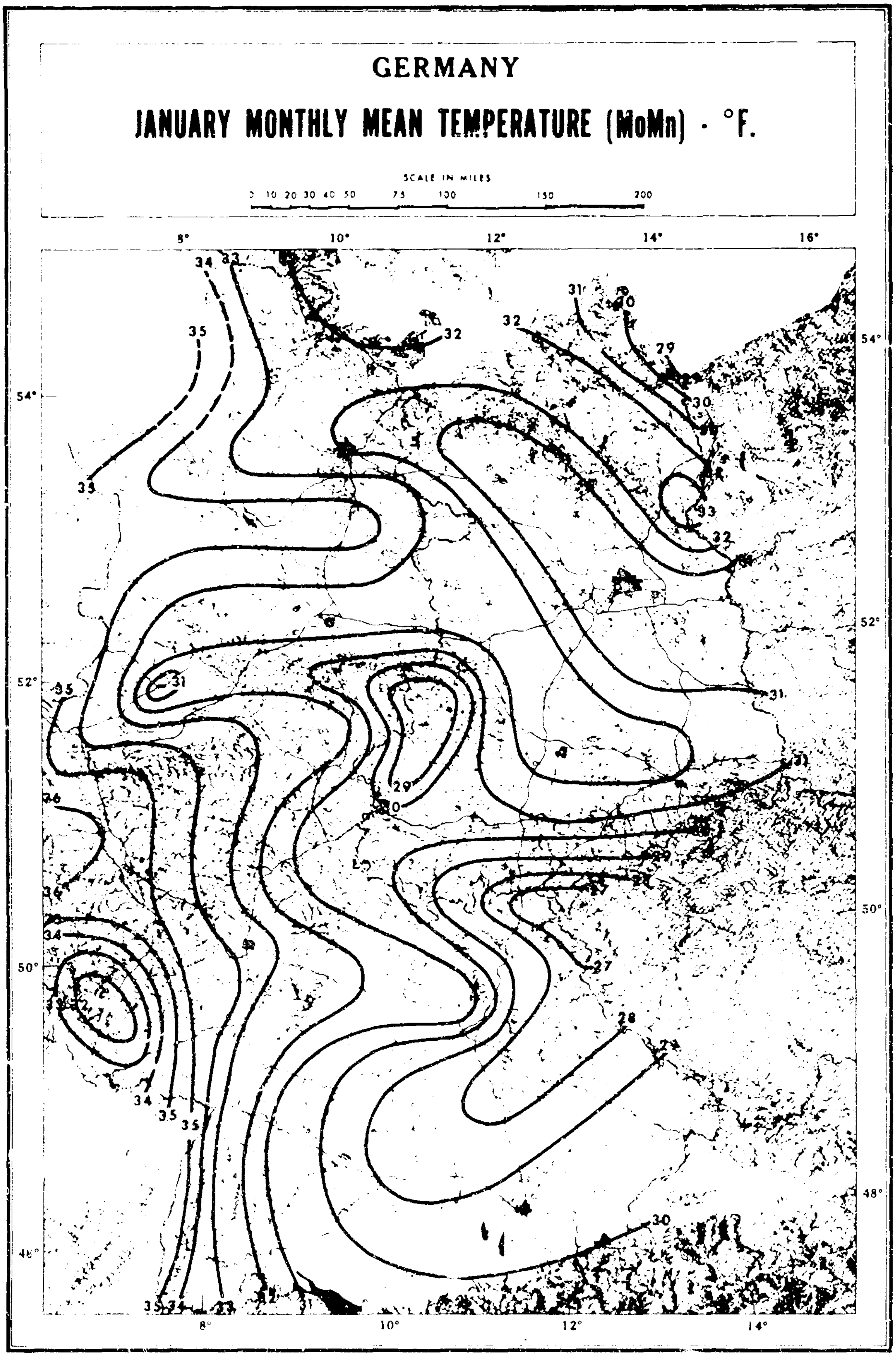
GERMANY
JANUARY MONTHLY MEAN TEMPERATURE (MoMn) · °F.
SCALE IN MILES
0 10 20 30 40 50 75 100 150 200
8° 10° 12° 14° 16°
54° 52° 50° 48°
35 34 33 32 31 30 29 28 27 36

Figure 5c

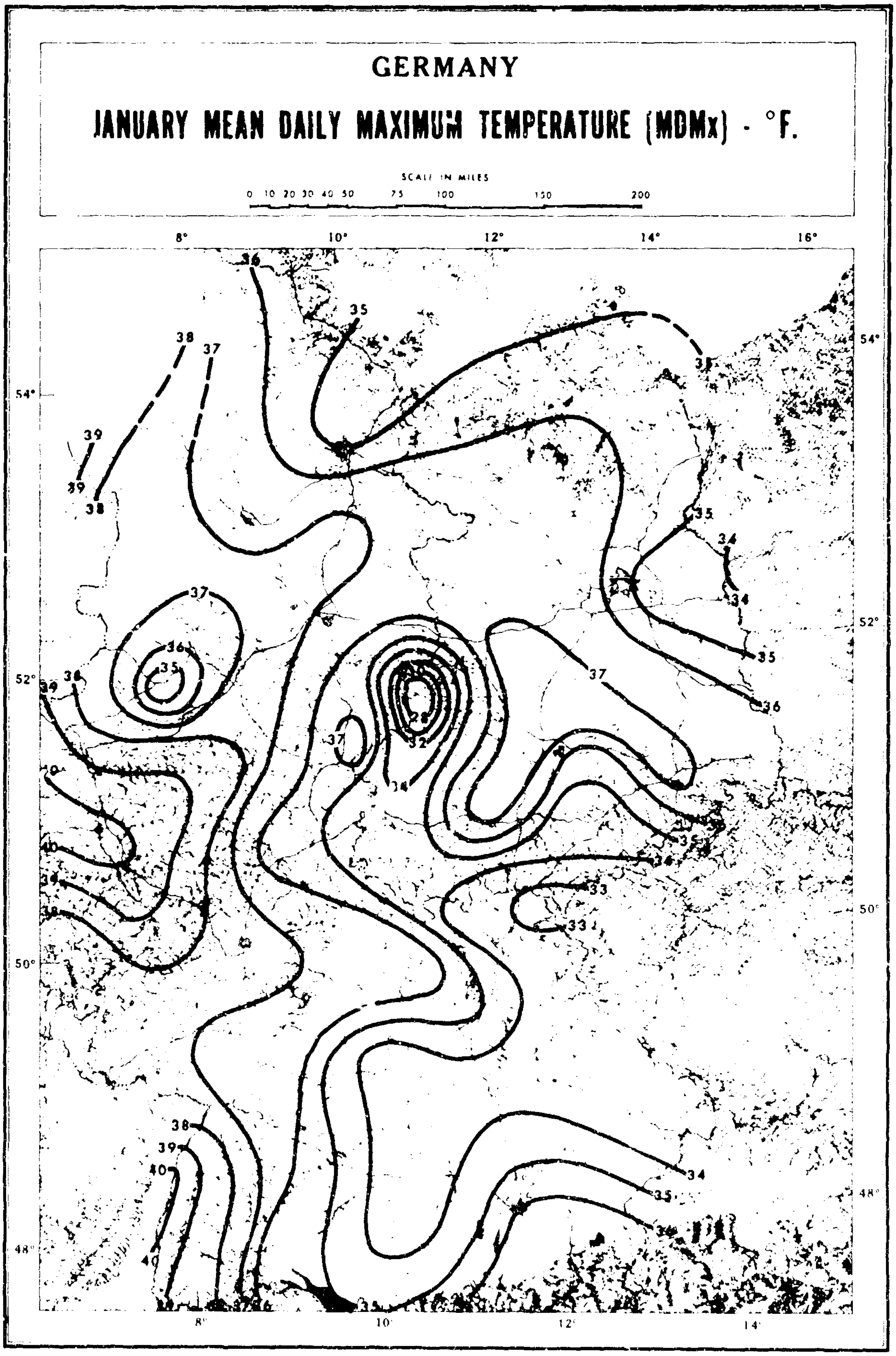
GERMANY
JANUARY MEAN DAILY MAXIMUM TEMPERATURE (MDMx) - °F.
SCALE IN MILES
0 10 20 30 40 50 75 100 150 200
8° 10° 12° 14° 16°
54° 52° 50° 48°

Figure 5d

GERMANY

JANUARY ABSOLUTE MAXIMUM TEMPERATURE (AbMx) - °F.

Figure 5e

The Stuttgart area* of Germany was a random sample to test the use of isothermal maps for predicting hourly distribution of temperature. The required essential data for the Stuttgart area are:

AbMx = 58°F MoMn = 30°F AbMi = -4°F

The above-listed summarized data for the Stuttgart area may be used with the General-purpose Nomograph to assess the frequency and amount of January temperatures. From the 50-year map data hourly temperature frequencies were predicted.** These are given in line F of Table V.

3. Reliability of predictions for Stuttgart area

In Table V, line D gives the observed hourly frequency record, machine-tabulated, for 5 Januaries.*** Line E gives the hourly frequencies from the 5-year summary record in line D.

It is believed that the predictions in line F, made from the 50-year map data, are just as good or better for operational purposes than the recorded hourly frequencies from the original 5-year machine-tabulated records or the predictions from the 5-year summarized records.

4. Constructing maps of temperature probabilities

Let us illustrate one use for the temperature probabilities developed from essential data by using the Nomograph. Suppose we wish to construct a January map of Germany showing the minimum temperature probabilities for 9.7% of the time, or 3 days in January. This will be done in the following steps:

a. Secure essential data

We have decided to use the Alternative Nomograph, so we will need MDMx, MDMi and AbMi. We will secure these essential data from the vertex of each degree quadrangle. For example, quadrangle A, on Figure 5d, 5b and 5a. Table VI gives the essential data so secured.

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*This is an area where hourly records have been kept and tabulated which are of sufficient length to lend validity to the present nomographic method. It should be noted, especially, that the predictions are not for the Stuttgart weather station, but represent the general area in the vicinity of the relevant isotherms.

**See Appendix C for detailed steps in predicting

***Tabulated at Asheville, N.C., for Weather Corporation of America (WCA)

Table V. Machine-Tabulated January Hourly Temperature Frequencies Compared with Frequencies Predicted Manually from Summarized Records and also those predicted from Map Data. Stuttgart Vicinity in Germany.

AbMx	MoMn	AbMi	A B C	[AbMx] .323%	1 1%	1 5%	1 10%	1 20%	1 30%	1 40%	1 50%	1 60%	1 70%	1 80%	90%	99%	99.5%	1/310 10 99.677%	1/620 20 99.839%	1/930 30 99.892%	1/1240 40 99.919%	1/1550 50 99.935%	1/1860 60 99.946%	1/2170 70 99.954%	1/2480 80 99.960%	1/2790 90 99.964%	1/3100 100 99.968%
57	33	-2	D	57	51	46	43	39	37	35	34	32	31	26	19	13	11	-4									
57	33	-2	E	57	54	51	47	42	39	34	30	25	20	16	12	6	2	-4	-7	-9	-10	-11	-12	-13	-13	-14	-14
56	30	-4	F	58	54	51	46	43	39	35	30	27	22	18	15	10	6	2	0	-2	-3	-4	-5	-6	-6	-7	-7

A - Ratio probability in 31-day month(s) from 10 years (1/310) to 100 years (1/3100).
B - Number of given month involved.
C - Percentage probability for given value on a 100-unit scale from .323% (323 in 1000) to 99.968% (99,968 in 100,000).
D - Observed record, machine tabulated at Asheville, N.C., National Weather Records Center 5-year record.
E - Predicted from summary records (AbMx, MoMn and AbMi) in A. 5-year record.
F - Predicted from map data - three isothermal maps of Germany 50-year record.

Table VI: January Minimum Temperature Probabilities at 19 Different Frequency Intervals for 3 Degree Quadrangle Locations in Germany.

Quad-rangle	Location Lat.	Location Long.	Map Data** AbMi	Map Data** MDMi	Map Data** MDMx	80.6% 25/31	64.5% 20/31	48.4% 15/31	32.3% 10/31	16.1% 5/31	9.7% 3/31	3.2% 1/31	1.08% 1/93	.645% 1/155	.323% 1/310	.161% 1/620	.108% 1/930	.081% 1/1240	.065% 1/1550	.054% 1/1860	.046% 1/2170	.040% 1/2430	.036% 1/2790	.032% 1/3100
						Probable Frequencies of Daily Minimum Temperatures																		
*A	51°N	07°E	-2°	31°	40°	35	33	30	28	23	19	15	11	8	5	1	0	-1	-2	-3	-4	-4	-4	-5
*B	52°N	13°E	-20°	26°	36°	31	29	25	22	16	10	4	-1	-6	-10	-14	-17	-19	-20	-21	-22	-23	-23	-24
*C	50°	11°E	-21°	24°	35°	29	27	22	20	13	6	3	-3	-8	-11	-16	-18	-20	-21	-22	-23	-24	-24	-25

*Each of these degree quadrangles (A,B,C) is marked on Fig. 4.
**The essential data needed for predicting (AbMi, MDMi, MDMx) were taken from isothermal maps Fig. 5a, 5b, 5d.

For example: At Lat. 51°N and Long. 07°E (Quadrangle A, near Köln) a minimum of 19°F may be expected at least 3 days in January or 9.7% of the time, and -2°F or lower, 1 day in 50 Januaries.

b. Compute and tabulate probable frequencies

Using the Alternative Nomograph, the probable frequencies of daily minimum temperature were computed for quadrangle A. (See Table VI.)

In the same way the data and probable frequencies were obtained for each degree quadrangle (B, C, etc.) and tabulated, as indicated on Table VI.

We are here interested in 9.7% probabilities, so we underline these in the table (Table VI). These underlined values will be used in constructing the 9.7% probability map.

c. Construct the probability map

On the map of Germany, at the various quadrangular vertices, plot the 70 or more minimum temperature values shown in the 9.7% (or 3/31) column, that is, for quadrangle A = 19; B = 10 and C = 6, etc. Draw the 9.7% isotherms through and among the plotted minimum temperature values.

This is the 9.7% map, and shows the minimum temperature to be expected at least 3 days in January in every part of Germany.

d. Wider application

Of course, corresponding maps can be drawn showing minimum temperatures to be expected for any level (80.6% to 0.032%), i.e., from 25 days in one January to 1 January day in 100 years or 100 Januaries.

The above procedures could be followed in constructing maps featuring frequency of daily maximum temperature levels (using MDMi, MDMx and AbMx data).

Similar procedures could be used for rainfall, or other climatic data. Or the procedures could be adapted to use of the General-purpose Nomograph and its appropriate essential data (AbMx, DMn, AbMi).

This procedure is applicable for any part of the world where essential summarized climatology data are available.

It is believed that the temperature data derived from such maps is sufficiently reliable to fall well within the calculated risks of military expediency, and may be used with confidence at least until better criteria are found and evaluated.

Summary

A. The value, use and construction of the 100-unit nomographs presented in this study are based on the assumption that the frequency distributions of measures of given phenomena differ from the normal according to patterns which are more or less inherent in their summary measures. The construction of the two nomographs depends largely on which values in the summaries are utilized as parameters in their make-up.

In Figure 1 and Table I, the 101 converted mean patterns (CMn), each with its unique series of converted predictive values (CPrV), depend for their utility entirely on four (4) parametric values. These summary measures are:

AbMx	-	Absolute Maximum
AbMi	-	Absolute Minimum
Mn	-	Mean or Average
	-	Length of Record

Given these 4 parametric measures, commonly available in summarized climatic records, the approximate details of a climatic record may be retrieved.

B. Some categories of summarized data include the average or mean of a series of extremes, i.e., the mean maximum (MMx) and mean minimum (MMi). In this case, these two parametric values together with the extremes may be used in the construction of the Alternative Predictive Nomograph (Figure 3).

Theoretically, the prediction from the two nomographs should agree (approximately) when applied to a given summary record. The anchor position (CMn = 0 and CMn = 100) from which all probabilities (CPrV's) are measured in Figure 1 is either the absolute maximum or absolute minimum; this is not as stable as the anchor position of mean maximum (MMx) or mean minimum (MMi) as in Figure 3.

C. The author believes that these two nomographs are fairly good instruments, but should be considered tentative, and should be subjected to rigorous tests and subsequent revision. Therefore, this investigator invites and welcomes suggestions for the revision or modification of these two prognostic instruments.

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APPENDIX A

ABBREVIATIONS

AbMx	=	Absolute Maximum The highest measure recorded in a given series of observations of a climatic or other variable.
AbMi	=	Absolute Minimum The lowest measure recorded in a given series of observations of a climatic or other variable.
Mn	=	Mean The sum of a series of measures divided by the number of measures, to give the average value.
DMn	=	Daily Mean The average of a given series of daily measures.
MoMn	=	Monthly Mean The mean of a series of monthly averages for a given month in each year of record.
MDMx	=	Mean Daily Maximum The average of the daily maxima (in this study, for a given month only in each year) during the period of record.
MDMi	=	Mean Daily Minimum The average of the daily minima (in this study, for a given month only in each year) during the period of record.
CAbMx	=	Converted Absolute Maximum The AbMx changed to 100 on the 100-unit scale.
CAbMi	=	Converted Absolute Minimum The AbMi changed to 0 on the 100-unit scale.
CMn	=	Converted Mean The mean occupying the same relative position between extremes as in unconverted observations, but expressed as a value on the 100-unit scale between 0 (CAbMi) and 100 (CAbMx).
CMDMi	=	Converted Mean Daily Minimum Average of the reduced daily minima converted to the 100-unit scale as in Table IV.

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CMDMx = <u>Converted Mean Daily Maximum</u>
Average of the reduced daily maxima converted to the 100-unit scale as in Table IV.

CPrV = <u>Converted Predictive Values</u>
The cumulative frequency predictive values associated with each of the 101 CMn's (left margin Table I and Table IV), e.g., CPrV's on line CMn 60.

PCMn = <u>Period Converted Mean</u>
See footnote Table I and Table IV.

APPENDIX B

PROBLEM SOLUTION: ASSESSING FREQUENCY AND PROBABLE AMOUNT OF 1-DAY RAINFALL, USING GENERAL-PURPOSE NOMOGRAPH

In this type of problem, we are given the 10-year record and use the Extrapolated section of the Nomograph or its associated Table to predict for decades beyond 10 years. The specific subject, April rainfall in New Orleans, was previously discussed (see Table I, ref. 7), but in the following problem the present Nomograph (Fig. 1) was used.

1. Statement of problem

Given: At New Orleans during a 10-April period (300 April days in 10 years) the monthly mean (MoMn) rainfall was 4.94" and the 1-day maximum (1-day Mx) was 5.8".

Required: What is the probable 1-day maximum April rainfall to be expected in 20 years? 50 years? 100 years?

2. Solution of problem

a. Find the CMn (1-day converted mean)

Formula:

$$\text{1-day CMn} = \frac{100\ (\text{MoMn})}{30\ (\text{10 April 1-day Mx})}$$

(Substituting)

$$= \frac{100\ (4.94)}{30\ (5.89)} = 2.81 \text{ or } 3$$

Therefore, 1-day CMn 3 pattern of CPrV is to be used for predictions.

b. Find the CPrV's

On the General-purpose Nomograph, follow along CMn 3 from the left margin to its intersection with the 20-year curve, thence upward to 124; to the intersection with the 50-year curve, thence upward to 146; and for the 100-year curve, thence upward to 168. These are the converted predictive April 1-day rainfalls. These CPrV's are more easily found on the equivalent table. Using the CMn pattern of 3 in Table I, follow along from the left margin until under column head for 20 years: 124; for 50 years: 146; and for 100 years: 168.

c. <u>Reconvert to conventional measures</u> (inches)

<u>Formula</u>:

$$\text{1-day maximum} = \frac{(10 \text{ April 1-day Mx})\ (\text{CPrV})}{100}$$

$$\text{20 April 1-day Max} = \frac{5.89''\ (124)}{100} = 7.30'' \text{ at least}$$

$$\text{50 April 1-day Mx} = \frac{5.89''\ (146)}{100} = 8.60'' \text{ at least}$$

$$\text{100 April 1-day Mx} = \frac{5.89''\ (168)}{100} = 9.90'' \text{ at least}$$

APPENDIX C

PROBLEM SOLUTION: ASSESSING TEMPERATURE FREQUENCIES, BASED ON 50-YEAR SUMMARY RECORDS, USING GENERAL-PURPOSE NOMOGRAPH

This is a step-by-step solution of the problem discussed in VI,2 of this report, with results given in Table V, line F.

1. Statement of problem

Given: The following essential data from isothermal maps, Figs. 5 e,c,a

AbMx = 58°F   MoMn = 30°F   AbMi = -4°F

Required: To assess the percentage frequency of January daily temperatures, based on 50-year summary map records, for the vicinity of Stuttgart, Germany.

2. Solution of problem

a. Reduce the 3 items by subtracting each from AbMx, so that:

AbMx = 0   MoMn = 28   AbMi = 62

The 50-year range is 62F°.

b. Find the 50-year CMn

Formula:

$$\text{PCMn} = \frac{100\ (\text{MoMn})}{\text{Range}}$$

(Substituting)

$$= \frac{100\ (28)}{62} = 45.2$$

PCMn 45.2 is for a 50-yr period record.

c. Find the 10-year CMn pattern equivalent to PCMn 45.2

In Table I, follow down the 50-yr column series of PCMn's (figures less than 100) to the one nearest 45.2. This is 45.5 and is found associated in the 10-yr table (follow line to left margin) with the CMn 50 pattern of CPrV's.

The 10-yr CMn 50 pattern will serve for prediction purposes.

d. Find the required CPrV's

On Table I, on the CMn 50 line, find the required CPrV under the appropriate column heading, e.g., 30-yr CPrV = 107; 50-yr CPrV = 110; 100-yr CPrV = 115.

e. Find what the 10-year range would be, corresponding to 50-yr range (62°F)

Formula:

$$\text{10-yr range} = \frac{100\ (\text{50-yr range})}{\text{50-yr CPrV}}$$

(Substituting)

$$= \frac{100\ (62)}{110} = 56.4$$

f. Find required percentage frequency temperatures

Formula:

$$\text{Percentage frequency temp.} = \text{50-yr AbMx} - \frac{\text{10-yr range* (CPrV's**)}}{100}$$

(Substituting)

$$\text{For 1 day in 30 years} = 58 - \frac{56.4\ (107)}{100} = -2$$

$$\text{For 1 day in 100 years} = 58 - \frac{56.4\ (115)}{100} = -7$$

These and other frequencies are given in Table V.

*As in step e above.
**As in step d above.

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DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U.S. Army Natick Laboratories	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

A GENERAL NOMOGRAPH FOR NORMAL AND SKEWED FREQUENCY DISTRIBUTIONS: CLIMATOLOGICAL AND OTHER APPLICATIONS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

LACKEY, EARL E.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
July 1967	44	12

8a. CONTRACT OR GRANT NO. b. PROJECT NO. 1T025001A129 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 68-40-ES 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) ES-26

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Earth Sciences Laboratory, U.S. Army Natick Laboratories, Natick, Mass.

13. ABSTRACT Extended experience in the construction and use of several different predictive nomographs covering a wide range of frequency distributions of various types of weather and other phenomena, suggested the probability that a universal series of patterns of frequency distributions might permeate the whole of nature. This study is based in part on the several nomographic patterns developed in previous studies. It assumes that all of the frequency distributions we are likely to encounter in practical climatology, whether symmetrical or asymmetrical (skewed), may be fairly well approximated by a family of cumulative frequency curves, provided they are plotted on such a scale that 100 units represents the whole range of observational experience in each.

The predictive patterns in the General Nomograph and its associated table depend for their operation on the numerical position of the mean (average) between the two extremes (maximum and minimum) in the frequency distribution, when the three related measures are reduced to a 100-unit scale. The means of frequency distributions having various degrees of skewness lie along a diagonal line from the lower left to the upper right of the basic section of the nomograph. Other lines (curved) trace the values of other percentile or fractional parts of the various distributions. The construction, use and reliability of this nomograph and its associated table are given in this report.

Similar predictive patterns in an Alternative Nomograph and its associated table are identified by the numerical position of: (1) the mean maximum between the absolute maximum and the mean minimum, or (2) the mean minimum between the

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13. ABSTRACT (Continued)

absolute minimum and the mean maximum, depending on which extreme is being explored. A 100-unit scale based on the above values is used in each case. The Alternative Nomograph thus illustrates the possibility of using parametric data other than means and extremes as the basis for a nomograph, if that should be necessary, or should prove to be a better basis for frequency prediction.

The essential summarized data for use with either nomograph may be secured from printed publications or from isothermal maps. How each source of summarized data may be used, for retrieval or predictive purposes, is shown and the results are verified by comparison with recorded data in the same vicinity.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Design	8					
Nomographs	9,2		10			
Skewed distributions	1					
Normal distributions	1					
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